Gender and Technology: Social Context and Intersectionality

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Research on gender differences in teaching and learning with, and designing for, technology has, at least, a three-decade span (c.f. Belenky, Clinchy, Goldberger, & Tarule, 1986, 1997; Winkelman, 1997). Scholars from K-12 education, higher education, adult and continuing learning, professional learning, and distance education (c.f. Anderson & Haddad, 2005; Boeren, 2011; Booth, 2010; Campbell, 2000; Caulfield, 2011; Franzway, Sharp, Mills, & Gill, 2009; Graddy, 2004; Kramarae, 2001; Maher, 1987; von Prummer, 1993, 2005); interface design and instructional design (c.f. Baylor, Shen, & Huang, 2003; Campbell, 2015; Campbell & Schwier, 2015); computer-mediated discussions and social media use (c.f. Correa, Willard Hinsley, & Gil de Zúñiga, 2010; Dwight, 2004; Gregg, 2006; Herring, 1996a, Herring, 1996b, Herring, 1999; Holmes & Meyerhoff, 2008; Raacke & Bonds-Raacke, 2008; Turkle, 1984), and other areas of focus have examined social media delivery formats, design of physical learning environments, pedagogical approaches and content, and graduate education from multiple perspectives, including access, accessibility, the digital divide, social justice, usability, effectiveness, inclusiveness, and sociocultural and political perspectives (c.f. Ball, 2007; Littlejohn, Foss, & Oetzel, 2017). The author and others have also explored gender issues in design practice (c.f. Campbell & Varnhagen, 2002), teaching, and assessment (Campbell, 2002; Lacey, Saleh, & Gorman, 1998). The literature is broad and rich.

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A Turn in the Scholarship

More recently, critical scholars have become interested in, and concerned about, intersectionality, in which "multiple oppressions" influence each other and create learning and working environments that exclude or marginalize various learning communities, among them adult women, women and girls whose native language is not English, women and girls living in poverty in rural areas with limited access, Indigenous females, and so on (c.f. Belkhir & McNair Barnett, 2001; Morse, 2003; Li & Kirkup, 2007; National Science Foundation, 2004). If we use gender as a defining lens, we must also consider emerging questions about gender identity, a political, social, and cultural challenge that becomes a design consideration.

Within the past year, public and academic attention has again been directed to the essential male culture of Silicon Valley and the high-profile cases of inequitable status career opportunities, and salaries of women in IT companies like Uber and Google (c.f. Simon-Lewis, 2017). That the culture has not much changed since the 1990s, and that some critics point to biology as a limiting factor in aptitude and leadership is cause for concern for those of us who reject access to creative and managerial opportunities based on sex. Do these "chilly climates" reflect the learning experiences of girls and women in public and higher education contexts?

What do we know about gender and learning and technology, and what questions still need to be asked? Has research since 2005 identified new challenges, new understandings, and new directions? What do social media add to the mix? Has this knowledge affected how we design learning environments, and even who designs learning environments? Have we seen innovations that enhance learning for girls and women?

This chapter begins with an overview of methodology and definition of key terms, followed by a quick review of research from the 1990s and early 2000s (although this research dates even from the time of learning machines and correspondence education), and proceeds to survey the more recent research that addresses questions about gender and design; gender, age and access; gender and accessibility and economic opportunity; gender, new technologies, and pedagogical approaches; and gender and geopolitical, sociocultural, and economic contexts. Finally, the chapter will conclude with summative learnings and implications for gender-related planning; learning design; design practice; design of learning spaces; pedagogical approaches; and usability and inclusion of sociocultural factors such as first language, geopolitical context, indigeneity, and economic circumstance.

Organization

To organize this work, I re-read my work from the late 1990s and early 2000s to refresh my understanding of the gender-related issues in pedagogy and design in that era. I found I was then able to return to the literature with fresh eyes and a richer perspective, informed by technological advances (e.g., social media), increasing complexities in the research about learners (e.g., gender identity), transformations in public schooling and in higher education (e.g., increased internationalization, reduced public funding, political and cultural struggles over content and representation), critical views of formal education (e.g., decolonizing the curriculum), progress in theory and practice in educational technology and design (e.g., use of cases, designer identity, design thinking), and reengaged public interest in gender issues in multiple sectors, especially in IT workplaces like Uber.

Positionality

I believe that all human activities, like design, or learning, are socially and culturally situated. That is, the research questions that we choose to address arise from our own experiences, cultural contexts, personal philosophies, political vantage points, and biases and assumptions; the methods with which we explore these questions are also informed by our epistemologies, experiences (including educational), and current social contexts and are influenced by our preferred research constructs, relationships, funders, participants, professional environments, and so on. As Creswell (2013) notes, "interpretations of the data always incorporate the assumptions that the researcher brings to the topic" (83). Sometimes, we experience new learning that disrupts our assumptions or beliefs. Such a disruption is occurring in Canada, currently, with the release of the report of the Truth and Reconciliation Commission's 94 recommendations for reconciliation with Indigenous peoples, based on the egregious history and continuing generational trauma of the Indian Residential Schools c.f. http://www.trc.ca/websites/trcinstitution/index.php?p=3**).** Educators, the justice system, faith-based groups, policy-makers – existing social, cultural, economic, and legal structures of society – are challenged to acknowledge and work to resolve effects of oppression and colonization on Indigenous communities. Being compelled to consider, and design with, and for, alternative ways of knowing is a fundamental challenge to one's designer identity. For the purposes of this chapter, I am positioned as a Canadian, feminist, post-structural researcher whose research always has a gendered lens. I pursue questions of identity, power, authority, and language, particularly as they unfold in instructional design practice, higher education structures and lifelong learning, and engagement scholarship. This identity is reflected in my sense-making of the literature I identified to include in this study.

So, what is included? Beginning with the research discussed in the papers I had written almost two decades earlier, I conducted a search using the names of the researchers involved in gender research at the time. Several of these researchers had moved on to different areas, but many had continued in the same area of work, connecting with new colleagues, sometimes working in different contexts (e.g., a focus on computer-mediated communication evolved into research on blogs (e.g., the work of Susan Herring). Using numerous databases held in the library at the University of Alberta, for example, ProQuest, ERIC, as well as Google Scholar, Academica.edu, and ResearchGate, delimited by the dates 2000–2017, I searched for "gender," AND learning, teaching, higher education, design, technology, learning technology, public education, educational technology, instructional design, learning design, social media, ICT, workplace, adult learning, distance education, curriculum design, blended learning, blogs, online learning, professions and disciplines (e.g., engineering, teacher education, IT), access, and digital divide. These combinations and recombinations resulted in a snowball effect, leading me to additional resources. I also searched for curriculum resources, conference programs, reports from task forces and committees, and stories from popular media sources. I included international sources in particular those from Europe, Africa, the Middle East, South Asia, and South America. Because the editors, in essence, rejected an approach of technological determinism and charged contributors to "focus on educational needs and cluster the field's scholarship around the role educational technologies play in the solution of those problems, rather than vice versa," I did not use technology-specific search terms (e.g., MOOC), although I did include terms reflecting ways of learning or learning contexts (e.g., online learning). Instead, I took a sociocultural lens to focus on issues of inclusion, access, equity, and engagement. I retrieved over 400 articles from these sources that I then examined for recurring themes and approaches, setting aside those that may have described interesting research whose focus was not repeated in other literature I surveyed.

Finally, and essential to the sociocultural lens through which I've filtered by my understanding, and presentation, of the findings of my review, it is necessary to define two important terms, "gender" and "intersectionality."

The Meaning of Gender

It is important to problematize the term "gender," as gender is understood and implicated in different ways among cultures, through language, and in time, I propose that the research and practice we appreciate in 2017 reflects evolving conceptualizations of gender. Tuula Heiskanen, University of Tampere, Finland, references the work of Joan Acker (1997) and West and Zimmerman (1987) in acknowledging that gender has consistently proved to be complicated and complex. In North American academic writing, gender and sex have almost become interchangeable when one refers to social roles, while the other refers to biological attributes. Heiskanen (2006) explains that a concept of gender that includes relevant aspects of social structure and social process is necessary to guide organizational interventions, such as design. In this view, gender is conceptualized as an activity, rather than a state. Heiskanen traces the notion that gender is something that one does, rather than something one is, back to Birdwhistell (1970) and especially Butler (1990) who "understand[s] gender as a relation among socially constituted subjects in specifiable contexts" (25). This performance notion of gender has framed the work of cybertheorists, who have studied whether online communicators are theoretically free to perform any identity, gendered or otherwise, that they can imagine…because text-based CMC filters out cues such as voice and physical appearance (suggesting that) online personae can evolve existences independent from their flesh-and-blood animators, shaped by the social interactions and the contexts they encounter online (Herring, 2004, 426).

Interested in how gender identity is implicated in different positions in social organizations (e.g., schools and workplaces), Acker (2000) understands gender as “patterned, socially produced distinctions,” proposing that gender inequities occur by way of unquestioned assumptions and values “rooted in taken-for-granted assumptions, values and practices that systematically accord power and privilege to certain groups” (in Heiskanen, 2006, 524). These practices may limit the activities of organizations in multiple ways by closing out, for example, alternative arrangements in organizing work or learning (e.g., online learning, telecommuting), in defining work or learning tasks for men and women (e.g., administrative vs leadership), in arranging the relationship between work or learning and family, and in judging collaborative forms of work or learning not aligned with an individualistic and competitive ideology (c.f. Inkpen et al., 1994).

Kirkup (2002) presents Harding’s model (1991), with its four aspects of gender, as a useful framework with which to understand the different kinds of interaction between women, men, and ICTs. Harding defines gender at its most simplistic as (1). a property of individuals; the ground of our gendered subjectivities, developed in the context of the other three aspects of gender: (2). Gender as a relation between groups, a property of material structures (e.g., gendered workplaces); (3). Gender as a property of symbolic systems, where representational systems, language, and imagery are gendered (e.g., the language of programming, and images like Lara Croft); and (4). Gender as identity, in all its complexities. Consider the young girl who encounters Lara Croft during gaming. And, although gender is not admitted as a way of determining how to distribute scarce resources (at least at loud), we have seen it resulting in gender-based access to ICT resources, for example.

From this point of view, a possible explanation for the status of women in ICT relates to the cultural “understanding” of technological work/skills, that is, these activities are part of what constitute masculinity (Cockburn, 1983, in Kirkup, 2002). Kirkup quips that “It is easier to change an activity with which you are simply associated than change your relationship with something that constitutes a key aspect of your identity” (5).

Consider these processes in the following description of Dr. MOOC (Box 1), a narrative-based MOOC designed to explore the role of the Internet in increasing health literacy among the general (Austrian) population, and how the physician–patient relationship is affected (Höfler, Zimmermann, & Ebner, 2017, p 107).

Kirkup (2002) points out that the rhetoric which suggests that new industries are both “gender blind” and that reward communication skills and feminine models of leadership (i.e., soft skills) is not borne out by research on the status of women in ICT professions. Woodfield’s (2000) study of a new high-tech ICT company showed that men were promoted and given management responsibility despite an acknowledgment by the company that they had poor management skills, accompanied by the unwillingness to give responsibilities to similarly qualified women who were

Box 1 Dr. MOOC
A global phenomenon noticed by general practitioners and specialized physicians is the tendency for patients to come to their appointments with previously acquired medical information from online sources. While the trend has health-related risks (e.g., substituting advice from popular, invalidated sources for professional advice), there is potential to democratize the access to medical knowledge (and its understanding), which has previously been a highly restricted privilege, guarded by (predominantly male) practitioners. The narrator, a key element of the design, is male…"a person the participants can trust in, since he is an expert in this field…His appearance on a weekly basis serves as the frame that organizes the process of content reception…(he) is non-focalized, as he knows, tells, and considers the thoughts and stories of each protagonist in his personal analysis….the audience thus gets more familiar with the case studies, the general practitioner's experience, and opinion" (p 55). Even though the designers of this *suspense peak narrative* MOOC acknowledged that the audience, or learners, are the most important design aspect of any MOOC their taken-for-granted assumption that a male physician would reflect the expert, trustworthy voice to all participants, regardless of sex or gender, reflects the creation of forms and symbols and patterned social interactions that represent gender divisions.

acknowledged to have these skills. Woodfield's study, and numerous studies since (Millar & Jagger, 2001) show that "gender is re-asserted and jobs acquire gender quite quickly in some communities of practice" (4).

According to Acker (2000) what really complicates change, or the success of intervention, is that the embeddedness of gendered assumptions in organizational (pedagogical) practices makes gender both pervasive and invisible; it is difficult to see that practices actually contributing to gendered consequences have anything to do with gender. More recently, growing sensitivity to gender identity and sexual orientation in Western education systems and organizations has compounded the complexity of these issues; globally, considerations of cultural and social values and practices result in the challenge of intersectionality.

The Meaning of Intersectionality

Through intersectional theory, identities are understood to consist of multiple social dimensions of difference, such as gender, race, sexuality, and/or class, and proposes that the complex interconnections between these dimensions have significant consequences (c.f. Davis, 2008). To ignore intersectionality in discussions about gender representation in learning environments has resulted in limited understandings of disparities in fields such as health care (see Box 2, Anatomy and intersectionality). For example, the effects of gender bias are shown to increase when intersectional determinants of health such as class, ethnicity, and sexuality are taken into account (Hankivsky, 2012). Adopting intersectional theory may encourage designers and educators to consider different representations of identity, social position, and processes of oppression or privilege.

Box 2 Gender Representations in Anatomy Textbooks
In a study of 17 anatomy textbooks used in Australian medical school curriculum, Parker, Larkin, and Cockburn (2017) found that less than 1% of the 6004 images reflected intersex or transgender people, suggesting that these communities have been persistently marginalized. Citing Bauer (2014), they point out that "ignoring intersections of gender with social characteristics such as ethnicity and age, medical research lacks a comprehensive understanding of the effects that heterogeneity have on health" (p. 110). In the same study, only a single representation of an Indigenous American (male) person was found, suggesting that representing more than one degree of difference presents a challenge to designers.

Research Is Socially Situated, and So Is Gender: A Context for Emerging Trends in Educational Technology Research

In this section, I provide a quick tour of research related to the intersection of learning technologies and gender circa 1980–2000. This era was characterized by a focus on technologies or tools and reflected the cultural domination of the West. Research methods ranged from quasi-experimental to descriptive and tended to relate to educational interventions on a fairly small scale. Researchers were interested in delivery formats (e.g., distance education), computer-mediated communication (CMC), software and game design, affordances of learning management systems and related implementation issues, access to broadband and ICT at home, school, and in the workplace (digital divide), career choices, technology adoption, and psychosocial barriers to participation.

The Cultural Deficit Model

Chikunda and Chikunda (2016) point out how the discourse of "opportunities toward education for all are there, the fault is theirs (girls) not the system" is ideologically laden with functionalist, instrumentalist views. In this discourse fragment gender equality is seen in a narrow sense that "includes physical access: the belief that once girls and boys are exposed to the same curriculum, taught by the same teacher, read the same book, there is equality" (p. 17). These authors observe that the assumption that "access" is sufficient for equality overlooks existing gendered social relations in school bureaucracies, curricula, teacher preparation and assignments, and the systems of instruction in the societies of which they are part. In terms of gender issues, prevailing discourses reflected a liberal feminist liberal interpretation, that is, how the context disadvantaged girls and women, and what interventions might be effective at "narrowing" the gaps, what those looking at issues of cultural difference, disabilities, etc. have termed the " deficit model" (c.f. Tong, 2014). In other words, women were problematized rather than technology.

> "The cultural deficit model stems from negative beliefs and assumptions regarding the ability, aspirations, and work ethic of systematically marginalized peoples. It asserts that (individuals) often fail to do well in school because of perceived 'cultural deprivation' or lack of exposure to cultural models more obviously congruent with (school) success…often enter(ing) school with a lack of "cultural capital" (Bourdieu, 1997, in Izarry, 2009), cultural assets that are affirmed by schools and often shared by school agents and therefore considered valuable" (Izarry, 2009, n.d.).

Research grounded in this perspective blames the victims of institutional oppression for their own victimization, using negative stereotypes and assumptions regarding certain groups or communities, thus overlooking root causes of oppression by localizing the issue within individuals and/or their communities. Interventions are then targeted toward the passive "challenged" person by others, rather than to the environment that, by its design, supports disadvantages. In other words, in the individual deficit model is the belief that it is the "challenge," be it mental, physical, or sociocultural, which causes the continuing inability of the individual to function normally. The cultural deficit theory is one lens that we can take to the problem of intersectionality, or multiple intersecting oppressions, such as those identified by Parker and others (2017) in the Australian anatomy textbook study. Of course, institutionalized systems (of learning, work, and living) are slow to react and transform, throwing more recent researchers back onto psychologically based explanations, such as women's lack of confidence and interest in ICT, women's poor self-efficacy, a lack of role models in schools and professions. Kirkup (2002) "want(s)to place them in the wider context of social learning, and of ICT related skills as grounded in communities of practice with dynamic gender systems" (p. 5).

Methodological Issues

Criticisms of "the first two decades" of research in educational technology include the "ill-conceived and unproductive" emphasis on questions such as "Is a technology-based method better than a non-technology-based one?" (Schrum, 2005, p. 218); the focus on both the "lack of guiding theory as well as the failure to provide adequate empirical evidence on many salient outcome measures" (Bebell, O'Dwyer, Russel, & Hoffman, 2010, p. 31); the "focus on technology access instead of measuring the myriad ways that technology is being used, (assuming)s that teachers' and students' access to technology is an adequate proxy for the use of technology" (Bebell et al., 2010, p. 34), and often defining technology use as a single dimension. Bebell and others (2010) also urge researchers to "consider the statistical and substantive implications of the inherent nesting of technology-related behaviors and practices within the (school) context" (p. 46), which addresses the social situatedness of technology-based teaching and learning.

In 2002, Winn discussed educational technology research moving through four "ages": the age of content, or focus on cognitive science; the age of message design, or format, in which individual differences were considered; the age of simulation, or focus on interaction, in which learners were encouraged to take control of the material (i.e., constructivism); and, finally, the focus on learning environments, in which the environments could be either natural or artificial, "existing only through the agency of technology" (p. 335). Winn observes that an advantage of looking at social interactions is that the "conversations among students are themselves useful data sources. Thus, discourse analysis can shed light on the processes and products of learning" (p. 340). Winn cites Malarney's (2002) study showing that technology alone is not sufficient to create a successful learning environment, that "features of learning communities, where the responsibility for helping students is widely distributed, must be developed if learning is to occur" (Winn, 2002, p. 342). Reeves (2000) concurs with Winn that educational technology research has often been disconnected from practice, in that studies have been designed for laboratory settings, assuming that factors could be controlled; and practitioners have been hard-pressed to find, interpret, and actually use the information, materials, and programs of activities that the research has created. Both Reeves and Winn champion design-based, or development, research as an anecdote to this problem. Reeves locates a range of researcher goals in a simple taxonomy of six research methods that reflect various epistemologies and paradigms, in particular researchers with theoretical, empirical, interpretivist, postmodern, development, and action goals.

Goals of Research

For example, Reeves (2000) characterizes researchers with "interpretivist goals" as focused on "portraying how education works by describing and interpreting phenomena related to teaching, learning, performance, assessment, social interaction, (and) innovation" by "drawing upon naturalistic research traditions borrowed from other sciences such as anthropology and sociology" (p. 6). This perspective has only recently been evident among instructional technologists and is viewed with some suspicion (Reeves quotes a source describing qualitative research as "useless," p. 6). Interpretivist researchers use ethnographic methods such as observations, case studies, interviews, and other qualitative data.

Researchers with postmodern goals often employ critical theory methods such as deconstruction of "texts", or the technologies and systems that deliver them, to examine the assumptions underlying contemporary educational programs and practices with the ultimate aims of revealing hidden agendas, binary oppositions, and/or empowering disenfranchised minorities. Reeves (2000) describes this paradigm as "very rare" in our field although "increasingly evident among researchers with strong multicultural, gender, or political interests" (p. 6). He cites the difficulty postmodern researchers have in finding scholarly outlets for their papers as one reason for this. Incidentally, this has been my own experience as a researcher concerned with gender and power.

Researchers with development goals are focused on the dual objectives of "developing creative approaches to solving human teaching, learning, and performance problems while at the same time constructing a body of design principles that can guide future development efforts" (Reeves, 2000, p. 7), such as the theoretical model of anchored instruction developed by the Cognition and Technology Group at Vanderbilt.

The works of Martin, Diaz, Sancristobal, Gil, Castro, and Peire (2011), and of Hsu, Hung, & Ching, (2013) illustrate how interest in, research about, and subsequent development of understandings and interventions in and/or design of learning environments are socially situated. Martin and others analyzed the predictions of the *Horizon Reports* 2004–2011, studying metatrends and evolution flows of the technologies predicted to be ascendant in those reports. Hsu, Hung, and Ching completed a bibliometric study of educational technology articles published in six SSCI-indexed journals over 10 years.

Bibliometrics and Research Focus

Based on the number of technologies forecasted by *Horizon Report* (*HR*), the "SocialWeb" was the most promising technology from 2005 to 2008. However, this changed in the 2009 *HR*, as only one related technology was forecasted, namely, the personal Web, which is less related to experiencing social collaboration than to "using social-based knowledge to build user-centered content" (1896). This trend continues in the 2010 *HR* which predicted no social Web technology. The long-term forecast, 2012–2013, focused on social operating systems that organized social networks around people instead of around content, including "collective intelligence," based on knowledge generated by large groups of users, such as on Wikipedia.

The "SocialWeb" was predicated on collaborative tools for communication among learners over the short term, including virtual collaboration tools (known as social computing) and the broadcasting of user-created content such as blogs, wikis, and audio/video-based tools like YouTube. This phenomenon of social networks in the educational environment, based on the idea of providing students and educators with advanced communication and collaboration tools and the creation of a network of contacts to support a highly engaging environment, put the user actively at the center of action. "The Web 2.0 philosophy, in which content is the key driver of new media applications and collaboration and social interaction are the driving forces behind opinions (e.g., through blogs), knowledge (e.g., on wikis) or the sharing of digital artifacts…inevitably lead to the emergence of virtual communities that enable social networking" (p. 1896). Jarvis (2009) characterized audiences as having "shifted from a niche of masses to a mass of niches, in which service personalization, content creation, and knowledge acquisition are driven by social interaction" (in Martin and others, 2011, p. 1896). If the one-size-fits-all paradigm no longer fits and the learner is the center of the educational process and thus requires adequate technological support to create, communicate, collaborate on, and access personalized services, the focus must then shift from intervening with the user (the deficit model) to intervening with the social/technical environment.

Similarly, today's students have grown up with a new class of technologies that the previous generation might not have imagined, including smartphones with video capability, which deeply impacted our society, changing the way we communicate with and keep in touch with one another. These devices are changing the way we work by supporting a variety of applications (including typical office applications, the Internet, and e-mail), the way we spend our spare time (e.g., with video games, Internet videos, and podcasting), the way we obtain and share information (including through GPS navigators, augmented reality, Web surfing, and blogging), and the way we learn. Some *HR* predictions were right, for example, social networks, user-created content, virtual worlds, mobile devices, and grass-roots videos; but others did not have the expected impact, for example, learning objects and ubiquitous computing. Martin and others (2011) point out that the increasing importance of mobile devices in education is fostering all the technologies related to them because of the social and cultural transformations involved in using them. Consequently, for example, our research interests continue for gender implications in discourse analysis of social media.

In their bibliometric study of research trends, Hsu et al. (2013) use "Feenberg's Critical Theory of Technology" (2009), a framework to analyze technologies and technological systems at multiple levels, to interpret and reveal thematic cultural clusters across six journals in five countries. According to Feenberg (2009), technology is a two-sided phenomenon that involves the operator and the object. Where both the former and the latter are human beings, technical action is an exercise of power. They show that Taiwan, among the Top five prolific countries in EDTECH research, showed different research interests compared to the other four countries that showed similar research interest. They posit that research directions in Taiwan had been highly influenced (i.e., restricted) by government policies, to wit, all e-learning-related policies fell under the framework of "National Program for e-Learning" which comprised three major goals: (1) improve public welfare; (2) develop Taiwan's e-learning industry; and (3) stimulate e-learning research, especially in new learning technologies, methodologies, systems, and tools. Scholars with the aforementioned research foci could more easily obtain grant support from the government (Hung, 2012, in Hsu et al., 2013). Because the "National Program for E-learning" framework encouraged the development of new learning technologies, it resulted in the phenomenon of scholars in Taiwan generating large numbers of publications on the topic of "Automated Instructional Systems"(p. 694). In other words, government policy and/or ideology, through funding mechanisms, direct(s) research agendas, for example, in Europe (c.f. SHARE, http://www.share-project.org/home0.html).

Hsu et al. (2013) also show that articles published in a journal and the journal's aim and scope (and editorial policies) might also play the role of operator in shaping research trends in the field, supporting Reeves' (2000) observation that difficulty in getting one's research placed, in part because of research epistemology, may limit the field's exposure to emerging trends and concerns, especially where the research has postmodern (or post-structural) goals. Therefore, researchers' interests can be shaped and greatly narrowed if they want to publish in this top-ranking journal. When one journal has an exceptionally higher number of publications than others, the research trends of the field might be distorted and highly correlated with one single journal. For example, if qualitative research is not valued as credible or useful, narrative accounts of learning experiences (i.e., meaning making) may be rejected and therefore be discounted, a challenge when examining sociocultural perspectives related to technology. According to Hsu et al. (2013),

> the direction of technology development is top–down rather than bottom–up….This one-dimensional technical system (Feenberg, 2009) is likely to create resistance among the users….Feenberg suggested democratization of technology could be a solution by opening up technology to a wider range of interests, concerns, and feedback, which could lead to redesigning technology for greater compatibility with the human and natural limits on technical action….The spirit and nature of Web 2.0 generation of technologies encourage participation, creation, and sharing (and)...in general pose relatively low technical threshold for users, making it more likely to empower and involve users, which could help level the field for the operator and the object and encourage feedback that helps alleviate resistance (p. 701).

Gender and Learning Research Circa 1980–2005

At the beginning of the chapter, I recapped the work of researchers from the beginning of the so-called age of millennials, or digital natives, in terms of the issues they identified that were influencing the experience and success of girls and women with technologies for learning and work. Many of these concerns, and recommendations for amelioration, were located in individual behavior, "and not as the outcome of a network of deep and unconscious dynamic relationships" (Kirkup, 2002, p. 8). For example, in questions of who has access to the best technology at home, although the family is acknowledged as key to the production of gender and gender relations, the suggestion to create a family computer seems to forget that any technology brought into the family will acquire gender, depending on its status as a family resource and whose activities it supports (Kirkup, 2002). Findings from this period of research activity are summarized in Table 1: *Gender and technology research findings to 2005.*

In this section, I have provided a quick overview of the topics and methods related to gender and technology issues for approximately two decades, the 1980s, when personal computers became widely available; through the 1990s, and the rise of the Internet; and early 2000s, during which Web 2.0 was taken up. I have located these research trends in a sociocultural analysis of the research context(s) and have

Table 1 Research and recommendations circa 1990–2004

Issue	Findings	Recommendations
CMC	Discourse on CMC is gendered; gender preferences in discourse style exist In academic listservs, women used more hedges, politeness markers, language supportive of other participants' views; and …men made more strong assertions, violated conventional politeness norms, and adopted more adversarial stance toward their interlocutors Women's contributions are mistakenly attributed to others, or to luck more often than men's, and they receive less attention and encouragement from instructors Gendered power dynamics in an asynchronous academic discussion list, with men and high-profile members of the community dominating communication, even under conditions of pseudonymity Style of talk very dialogue-oriented, privileging the expository style most associated with male participants, reflected in adversarial relationships: Put-downs, strong, often contentious assertions, lengthy and/or frequent postings, self-promotion, and sarcasm If women contributed more than 30% of the conversation in CMC, they were perceived to be dominating conversation, by both men and women Women will behave consistently with maintenance of socio-emotional group process roles and men will behave consistently with a task-oriented role Concern about online gender harassment	Consider the effects of lack of social cues Discuss with class issues of identity, language use, and tone, acceptable ways to disagree with or challenge the views of others, and length and number of postings Facilitator modeling and support for diverse views and experiences, expressed in safety, must be explicit Swift interventions when interactions go awry

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Distance learning	Women have less access to resources Women are economically disadvantaged – Less access to higher education at a distance, less discretionary income for computers, less access to computer support Women suffer the "third shift" where their learning requirements are not valued equally Differences in the preferred learning styles of men and women make them respond differently to distributed learning methods; women less comfortable with isolation Female students use e-mail less frequently, spend less time online, and engage in fewer varied activities Families and other social structures in the community may marginalize women who are otherwise candidates for distance learning Inflexible schedules and deadlines for assignments and exams, requirements for technological tools may be out of women's economic reach Learning activities that may require travel, extra fees, and special arrangements, such as videoconferencing	Open registration Flexible deadlines Opportunities to borrow or rent IT Peer support Opportunities to meet F2F occasionally Collaborative learning activities Community-based learning centers

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Computers in the classroom	Classes are tedious and dull, too focused on productivity or programming Computer career options uninspiring and require "male" skills	Emphasize harmony with nature, concern for others, empathy, and compassion. Women show a preference for working with scientific concepts with social value, concern with consequences of action on others, and an ethic of care
		Gender-neutral, open-ended creative tasks such as collaborative writing
		Support the inter-relatedness of perspectives
		Teach about, and for, social and political activism and agency
		Avoid competitive and aggressive metaphors from games, sports, adventures, and war
		Evaluate visual imagery and design for bias
		Allowing for alternative representations through dynamic processes and the linking of verbal, visual, and aural information to support diverse learning styles, preferences, and experiences
		Include large databases of resources that invite the inclusion of experiences of women and other marginalized groups
Access, digital divide	Unequal access begins in the home and at school, ranging from a 2:1 ratio to a 3:1 ratio in favor of male ownership of computers Access becomes an effective gatekeeper for women Males have faster computers and more time on them Males dominate classroom, develop and foster community-based learning centers with guaranteed access to standardized learning technologies computing time Females feel excluded from computing environments Access relates directly to experience by influencing attitude and achievement	Place computers in accessible home spaces. Shared or family-centered activities on the computer, rather than viewing its use as an individual or isolated activity
		Cohort-based learning models
		"Rent-to-own" or "work-to-own," leasing, "evergreening," and interest-free loan

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Game design	Computer games too boring, redundant, and violent Gender ideologies are replicated in game design Girls prefer activities that are collaborative, based on narrative Computer arcades are male dominated (experience gap)	Girls as designers
		Stress characterization and relationships
		Games that feature simulation, strategy, and interaction.
		Games that are narrative-based
Interface and software design	Girls are alienated by individualistic activities based on metaphors of exploration, adventure, conflict, and competition Interface designs range along cultural dimensions, including masculinity and femininity Digital media simply replaces traditional media with no same problems in design, etc. Language and metaphor of ICT are not gender-neutral Highly structured computer-based designs available are counter-intuitive for women learners	Computing activities that are socially contextualized, that address social issues (e.g., poverty)
		Portray women as problem solvers rather than as victims or prizes
		Represent objects or issues studied holistically
		Games that are team-based
		No arcade-style designs
Post-secondary emphasis, STEM subjects	Large dropout of women students following increased recruitment Number of women diminish in STEM classrooms in upper levels	Change the first-year course curriculum Involve the most experienced teachers more with the women students in the early stages of their study.
		Unisex classrooms, female-only computer access
		Contextualize computer science
		Required computer literacy classes for all students
		Create more interdisciplinary courses

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Spaces	Computer labs are male-dominated and isolating Women feel unsafe because of design of labs and times of access Technological environments encourage autonomous learning, since cooperative learning was difficult to implement in fixed computer labs in which data could not easily be shared	Location of computing facilities in campus areas where women learners and women faculty members are concentrated
		Same-sex computer classes, as one learning option available
		Alternative designs of computer spaces, such as pods of four to encourage cooperative work
		Designated "women-only" lab time, with a less competitive climate and more personal interactions around problem-solving and computer anxieties
		Computing facilities that are supervised at all times, or especially in the evenings
Workplaces	"Chilly climate" Access to resources often status-based; women have lower status Fewer women are supported for continuing learning or training "Women's work", e.g., women hired as administrative staff	Organizational policies that explicitly address gender bias
		Mentors
		Family-friendly policies
		Clear expectations set
Models	Computers as productivity rather than creativity tools not appealing to girls Content not female-friendly Computing activities and environments are male-dominated	Teacher professional development
		Content should include female role models
		Encourage more women to major in STEM
		Encourage networking
Adoption of technology	More male than female faculty are early adopters Female faculty tend to use technology to create learning communities while male faculty tend to use technology more to support didactic approaches	Match technology use to teaching styles
		Design learning spaces to encourage collaborative uses of technology
		Ensure technical support available
		Professional development
Virtual worlds	Men have adopted female pseudonyms in order to belong to restricted conversations and once included, then have harassed participants for their views	Women must be cautious about publishing any information about themselves
		Be careful when approving pseudonymous posting

(continued)

Table 1 (continued)

Issue	Findings	Recommendations
Assessment, outcomes	Girls do not do as well in online activities (e.g., math)	Emphasize computer fluency: Girls" mastery of analytical skills, computer concepts, and their ability to imagine innovative uses for technology across a range of problems and subjects.
		Peer tutors
		Peer assessment
Identity	Feminization of the internet where women are targeted as commercial markets – As consumers rather than as citizens or learners	Women as content developers
		Networks that create opportunities for women in all areas of life
		Internet as community

proposed that the more recent research trends reflect less emphasis on experimental designs in favor of action, interpretivist, development, and postmodern goals for research (Reeves, 2000). Research since the mid-2000s, approximately 2005–2017, reflects the sociocultural context in which research in education is located in general.

Gender and Learning Research Circa 2005–2017

In the USA, the Institute for Women's Policy Research (IWPR, www.iwpr.org) tracks the gender wage gap over time in a series of fact sheets updated twice a year. Noting that in nearly every single occupation for which sufficient data are available, the gender wage gap had stayed essentially unchanged since 2001, meaning gender wage parity will not be achieved until 2059 if the pace of change remains the same (longer, if including ethnicity). Not surprisingly, projections show that equal pay would cut poverty among working women and their families by more than half and add $513 billion to the US economy. Why don't women choose higher paying jobs? There is considerable evidence of barriers to free choice of occupations, ranging from lack of unbiased information about job prospects to actual harassment and discrimination in male-dominated jobs, such as IT-related jobs under scrutiny in Silicon Valley and technology-related jobs in the "gig economy" (c.f. Priest, 2017). If we take the lens that one purpose of public and higher education, at its very best, is to even out socioeconomic and cultural disparities over time, presenting all learners with equal access to the social capital they need to acquire to succeed, and that the implementation of learning technologies in our schools is/was a tool for that purpose, research about its use accumulating over four decades, why do we not now have the outcomes that are reflected in measures such as the gender wage gap?

The answer to this question is, of course, very complex, and the question itself assumes causality. However, part of the understanding of this conundrum lies in enhanced awareness of the contexts in which research and interventions are designed, implemented, and evaluated (see the discussion of research trends, above). For example, the rapid advent of the "social Web" has contributed to global participation in social action in which knowledge is co-produced and represented quite differently than it was when print sources embodied such authority. Networks have rendered landlines almost obsolete; children in "developed" countries are born into communities in which personal computing is ubiquitous; evidence is contested; and gender roles are fluid. Technology has changed work; expectations about career trajectories have been disrupted. In fact, the "social order" is under constant disruption. In this context, gender is a social category rather than a biological determinant. Consequently, research about gender and learning technologies must become questions of sociocultural dynamics at home, in the community, at school, and at work.

Typical Research Questions

For example, in the late 1990s, as the Internet became easier to use and more accessible in education, the first learning management systems (LMS) like WebCT were developed to help manage resources and interactions with content and course participants. Research in this era was concerned with access, adoption, effectiveness and attitudes, and learning transactions. Questions reflected something akin to fatalism ("it's here, no matter what, we must use it") and an assumption that constructs, like gender, were stable and constant. "Why are female faculty slower to adopt learning technologies?"; "Why are adult female learners reluctant to approach technology?"; "Why don't girls like to play games as much as boys?"; "Do learners in an online course do as well as learners in a face-to-face setting?"; "Do women's discourse styles disadvantage them in CMC?" Questions like these focused our attention on differences, and suggested ways to narrow the so-called performance gap. For example, images representing IT careers were not "internationalized" simply by depicting a group that included a woman in a hijab working with male colleagues – such a solution did not consider how workplaces are gendered in various ways, and for various reasons, in areas of the world (see Intersectionalities, above).

For this chapter, I thought it would be useful and revealing to revisit productive areas of research, or compelling issues, over time. For some issues, this approach revealed progress in how we framed our problems, but for others, the questions were no longer relevant or significant. What emerges is a more nuanced and socially informed picture of gender-related issues in learning at all levels. These issues are interrelated in complex ways. For example, pedagogical practices must include an understanding of the influences of cultural and psychosocial factors. The same factors, plus the intersection of age, gender, access, and design must be considered in a discussion of the post-secondary learning environment. Stereotypes and implicit bias contribute to pedagogical practices, workplace climate, design, and representations in texts and language, intersecting with age, culture, and gender. In essence, though, if girls do not feel successful in science, technology, engineering, and mathematics, there will be fewer role models for artifacts such as texts and media, roles in public and post-secondary environments for girls, and gender influences on social systems and structures, such as the design of products and services and the climate in the workplace. This holds true globally. So, while I have identified seven domains of interest, they should each be read with the understanding that common threads run through them, those of unconscious (and conscious bias), cultural values, social context, political will, and unequal distribution of resources.

Culture and Gender Stereotypes: Bias and Representation

One of the enduring problems confronting educators in the disciplines.

of science, technology, engineering, and mathematics (STEM) is the disproportionate lack of involvement of females. Although females' lack of participation has been attributed to biased curriculum content, others attribute females' lack of interest to pedagogical approaches rather than to the inherent nature of the subject. Culturally grounded gender stereotyping is a significant challenge in its substantial influence on children's self-concepts. In a variety of ways, the media, peers, and adults communicate and reinforce gender-based stereotypes (Martin, Eisenbud, & Rose, 1995). For example, toys have a powerful influence on what children perceive as appropriate for boys and girls.

Toys designed for boys tend to be highly manipulative or electronic, whereas, girls' toys are less likely to be manipulative or have interchangeable parts (c.f. Caleb, 2000). Girls' toys also tend to feature interpersonal interaction, such as dolls, which encourage the development of social skills and relationships (Weber & Custer, 2005, p. 55), skills globally understood to be critical in the workplace.

Using a critical discourse analysis (CDA) approach, Ghajarieh and Salami (2016) studied Iranian educational resources, including textbooks, for English as a Foreign Language (EFL) at secondary, high school, and pre-college levels. The researchers sought to explore "whether the subversive gendered discourse of equal opportunities in male and female education as the subordinate discourses to the discourse of equal opportunities has been given sufficient backing" in Iran (p. 259). In CDA, language is considered a social practice occurring in a cultural context (be it an organization, a religious community, or a geopolitical region); issues of primary concern are those having the potential to discursively circulate power and ideology, for example "gender". As Sunderland (2004) notes, "the social issue and dramatic problem [in gender studies] is gender—an issue and often a problem for women and girls; in different ways, for men and boys; and accordingly, for gender relations" (Sunderland in Ghajarieh & Salami, 2016, p. 251). As demonstrated in the study of Australian anatomy texts, the marginalization of different minority groups and the underpinning of power imbalances in language, represented in verbal and visual texts and spoken language, ensure the dominance of powerful groups over other groups, including women. CDA focuses on text analysis to explore power, ideology, and identity, that is, the construction of knowledge, power, and identity through the close analysis of language texts (Ghajarieh & Salami, 2016). Sunderland's model of

CDA stresses the representations of male and female social actors through gendered discourses in text and reveals how instances of discourse "constructs, reiterates, or subverts ideology and social power" by examining the lexical and grammatical items that are chosen among all choices available to text producers within a gendered discourse (Ghajarieh & Salami, 2016). For example, would female actors be individualized and functionalized in spheres that were not "traditional?"

Employing this approach, Ghajarieh and Salami (2016) compared different samples from one Iranian EFL textbook, finding that no female actors were functionalized as "college student," but that male actors were individualized through masculine pronouns (e.g., "he") and functionalized as perspective college students, as in the following example, "He is working hard. He wants to go to university. He plans to study physics. I think this is a good end" (High school level, Book III, p. 23). In this case, female social actors functionalized as students were not assimilated as a group of students studying together with male students; the related images featured male and female students as separate groups. "This notion indicates that the functionalization of male and female social actors was defined only within a narrow perspective in line with the notion that women and men should be separated in public places, including educational settings" (p. 266). Furthermore, in the textbooks, female social actors were not individualized and functionalized in high-level jobs. Male social actors were represented in 89 cases as engineers, bus drivers, policemen, scientists, and dentists/doctors, while female actors were not represented at all in these professions, for example, "Mr. Amini is a doctor"; "Even though he was a computer engineer, he didn't know how to fix the computer." Furthermore, these representations support the discourse of "Women's marginalization in sciences, technology, and medicine" and resist the discourse of "equal education opportunities for both men and women." This is important to note since distorted representation of reality may convince the reader that the excluded identities and groups are not important. "The resistance against the discourse of equal education opportunities for men and women in Iranian EFL textbooks show inclusive education has yet to be achieved in the education system of Iran" (Ghajarieh & Salami, 2016, 267). Since school educational materials can mirror curricula used in the education systems of many countries, curriculum designers and textbooks writers need to consider policies, school textbooks, and material for intersections in gender, sexuality, race, ethnicity, religion, and other individual differences in education.

The "Gender Schema Theory" is another frame for understanding and intervening in how learners may actively seek gender-related information which will serve as a guide for their own conduct (Navarro, Martínez, Yubero, & Larrañaga, 2014). For example, with regard to gendered color preferences, girls can develop a stronger preference for pinks, purples, or reds when they notice that other girls wear clothes and accessories in these colors, whereas when boys make the same observations, they can reach the conclusion that pinks or purples are not suitable for boys and will avoid wearing these colors. Navarro and his colleagues (2014) observed that learning and the interiorization of these gender schemata "may influence social information processing, the undertaking of tasks and decisions making related with colors" that should be taken into account when planning educational actions, such as developing visuals, intended to modify gender stereotypes (p. 160).

Woods, Comber, and Iyer (2015) found their approach to inclusive educational design on principles of social justice, which require that "the curriculum and pedagogy offered recognises the unique and community characteristics and strengths of all children, their languages, ways of knowing, cultural and social beliefs, values and practices" (p. 46). They describe the foundations of their work coming from approaches broadly conceived as sociocultural, critical theorizations of literacy, including feminist, postcolonial, and post-structuralist orientations to issues of race, gender, sexuality, class, locale, and disability, or a "three-dimensional approach to social justice" (c.f. Fraser, 2009). In terms of curriculum design, learners will see their own languages, values, ideologies, interests, and communities reflected in the curriculum and pedagogical approach. The approach requires recognitive, redistributive, and representational action, with the intent of widening access "to the dominant skills, knowledges and understandings of education systems and society more broadly" (Woods, Comber, and Iyer, p. 50). The authors utilize this critical lens in their approach to game-based learning (GBTL), in which they use games as objects of study of cultural phenomenon, as well as learning products designed by students. "Activities Frame," one of the four pedagogical models they describe, includes studying an element of a game, for example, a critical analysis of gender representation, as well as playing the game to learn something, for example, cooperative play. An obvious response is for teachers in programs of curriculum design to learn about these approaches and exemplify them in their own practice. GBTL thus can be based on a "multiliteracies" framework that reflects on, and is reflexive about, designing for difference. An explanation of this framework for learning design is described in Box 3, *Multiliteracies*.

With regard to stereotypes about math and science, two are prevalent, that is, that girls are not as good as boys in math, and scientific work is better suited to boys and men. As early as elementary school, children are aware of these stereotypes and can express stereotypical beliefs about which science courses are suitable for females and males (c.f. Nosek, Banaji, & Greenwald, 2002). Furthermore, Buck and colleagues found that girls and young women have been found to be aware of, and negatively affected by, the stereotypical image of a scientist as a man (Buck, Plano Clark, Leslie-Pelecky, Lu, & Cerda-Lizarraga, 2008).

Discussing the cultural construction of computers as male, Sherry Turkle (2001) recounted a story about negative stereotypes.

> When I was a girl, I once wanted to build a crystal radio. My mother, usually very encouraging, said no, don't touch it, you'll get a shock. And I began to become reticent about such things as building crystal radios. It wasn't that I didn't want to build it-I wasn't phobic. But somehow, this just wasn't what girls did. I became reticent. Interview with Sherry Turkle. http://www.priory.com/ital/turkleeng.htm

Research has consistently found that "stereotype threat" adversely affects women's math performance to a modest degree (Nguyen & Ryan, 2008), accounting for as

Box 3 Multiliteracies

In 2000, the *New London Group* proposed "multiliteracies" as a framework that could provide a socially just and inclusive approach to teaching literacy. The framework supports transformative learning that takes into account the personal resources that learners bring to knowledge construction. A designer using this approach develops "grammars" that are learned along with elements of visual, audio, gestural, spatial and multimodal designs. A key element to this design practice actively engages learners in both designing texts and redesigning them to reflect new meanings. Four pedagogical components are involved: (1) situated practice, which situates learning in meaningful sociocultural contexts; (2) overt instruction, involving the teacher to make explicit links; (3) critical framing, "denaturalizing" concepts learned; and (4) transformed practice, which encourages learners to apply new learning in different contexts or sociocultural routines (c.f. Giampapa, 2010; Leman, Macedo, Bluschke, Hudson, Rawling, & Wright, 2011; Macedo, 2005; Prasad, 2013). Kalantzis and Cope (2005) present the multiliteracies framework as "learning by design," for example, where students produce a variety of multimodal texts, which are then used as learning resources so that their peers can use critical framing leading to the redesign of the texts. Imagine a group of learners designing a storyboard to create a digital text, perhaps a video, during which the teacher may ask them to reframe their thinking about the gendered archetypes they encounter in many videogames. How might these narratives be transformed to be inclusive? Woods et al. (2015) promote this kind of learning for taking into account individual differences, "along with differences in values, lived experiences, different ways of gaining knowledge as it takes account of individual meaning making and student life worlds… (and reflects) learning as being about transforming thinking and enacting a cultural transformation" (p. 68).

much as 20 points on the math portion of the SAT (Walton & Spencer, 2009). Stereotype threat suggests that a female student taking a math test experiences an extra cognitive and emotional burden of worry related to the stereotype that women are not good at math. For a visual representation of the effect of stereotype threat, see Fig. 1, below (Cooper, 2006).

However, Goode and others (2005) found that when the burden is removed by telling students that women and men performed equally well on the SAT, the women performed significantly better than the men. Of interest, culturally speaking, in South and East Asian cultures, where the numbers of STEM graduates de Corte (2010) are high, including women, the basis of success is generally attributed less to inherent ability and more to effort (Stevenson & Stigler, 1992). See the discussion of post-secondary education, below, for more research about "stereotype threat."

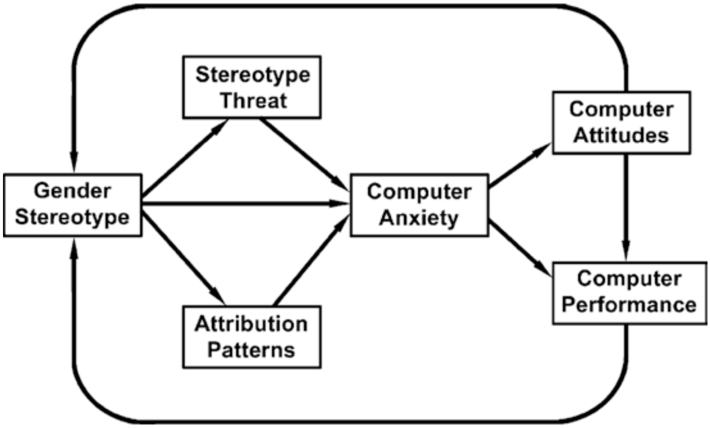

Fig. 1 Stereotype threat. (From Cooper, 2006, 334)

Discussion

This section presented several theoretical frames for understanding prevalent discourses that may influence a designer's decisions about curriculum, pedagogical approaches, design of educational materials, and structures of learning activities. For example, the intersectional analysis of the Australian anatomy textbooks presented earlier revealed a dearth of images of women in professional environments, portrayed indigenous actors in least powerful and stereotypical roles, and ignored the presence of LBGTQ+ individuals as exemplars.

Critical discourse analysis (CDA) focuses on text analysis, including visual representations, to explore the construction of knowledge, power, and identity. This approach considers language as a social practice occurring in a cultural context. Language construction, while intentional, reveals unconscious bias.

Gender Schema Theory assesses how learners may actively seek gender-related information which will serve as a guide for their own behaviors. Navarro and others (2014) observed that gender schemas are interiorized and should be considered when designing educational activities. While they were silent on the influence of culture, ethnicity, age, sexual orientation on gender schemas, they concluded that schemas may be "disrupted" or challenged during the design process.

Other researchers, like Fraser (2009) use critical theory to understand, evaluate and design curriculum. Feminist, postcolonial, and post-structuralist orientations to issues of race, gender, sexuality, class, locale, and disability are examples of "social justice" approaches to constructivist design. A case study of a design approach to a graduate course for indigenous learners, in which the design approach and resulting design reflect a postcolonial orientation is presented in Chapter (?) Note that this is the chapter by Janes, Makokis and Campbell.

Designers should be careful not to trivialize cultural norms in an effort to disrupt gender schemas and other discourses. The author witnessed this mistake firsthand when, during a professional meeting, a participant was advised to simply "put a hijab" on an image of a female computer engineer working closely with make colleagues in order to render the image acceptable to Muslim learners. The sociocultural context (women working with men in a professional context) was not considered.

Jacob Neilson and his colleagues have developed guidelines for internationalizing, and localizing websites (c.f. 2001 Neilsen & Tahir, 2001). His work on usability has been foundational for designing user interfaces that consider cross-cultural concerns (c.f. Chakraborty, 2009; Kaasgaard, 2000 ; Kompf, 2006; Mushtaha & De Troyer, 2009, 2012; Pawlowski, 2008). Likewise, the work of psychologist Geert Hofstede (1984, 1990, 2001) identifies six dimensions for distinguishing one culture from another. The dimensions are 1) Power Distance Index (high versus low); 2) Individualism Versus Collectivism; 3) Masculinity Versus Femininity; 4) Uncertainty Avoidance Index (high versus low); 5) Long- Versus Short-Term Orientation, and 6) Indulgence Versus Restraint (https://www.mindtools.com/pages/article/newLDR_66.htm).

Hofstede's work has been revisited by many researchers over three decades, recently demonstrating that cultural values can change over time in response to economic, environmental, political and social events (c.f. Wu, 2006). However, if used carefully his framework provides frames for designing for international learners, or for critically analyzing designs that already exist. The education of designers would benefit from activities to explore one's own tacit cultural assumptions and unconscious biases so as to be aware of inappropriate, or unhelpful, design decisions.

Gender and Psychosocial Factors

Goal 5 of the United Nations' "Education for All" policy aimed to provide equal opportunities for education, regardless of gender and place, by the year 2015 (Grimus, 2014). One might think that the present digital generation would be attracted to technology use regardless of gender. However, even once people cross the initial connectivity divide, differences such as level of education of the user and the user's parents, gender and ethnicity influence adoption. Studies across Europe and North America persistently show that levels of computer and Internet use are lower among rural youth, female youth, and youth from families with low levels of parental education (c.f. Jackson et al., 2008; Vandewater et al., 2007). Boys, older children, and middle-class children in developed countries benefit from more, and better, quality access to the Internet than girls, younger and working-class children. These benefits, including the development of writing skills, ability to conduct research, collaborate with others and create multimodal presentations depend not only on age, gender, socioeconomic status (SES), and geographical location, but also on amount of use and online expertise, for example, skills and self-efficacy shape and define the opportunities taken up by young people (Clark, 2013).

The vast majority of children at all grade levels in the developed world have access to mobile devices, but while boys report using mobile phones as gadgets, girls traditionally have perceived themselves as less skilled in terms of technology. Cotton argued in 2009 that “if this perception continues, it…can impact the types of jobs and courses that girls take…it could lead to a different type of digital divide” (in Grimus, 2014, np). They point out that much has to be done to teach girls about the technical and more advanced multimedia features of their mobile devices Further evidence was provided by a 2013 survey, of 2500 children (aged 9–16) and their parents, in Denmark, Italy, Romania, the UK, and Ireland, referring to gender differences in the daily use of smartphones (Mascheroni, 2013). The gap persists in higher education, where males show higher positive attitudes toward using technology for learning than females (c.f. Yau & Cheng, 2012). The mobile phone gender gap, in terms of usage, is observed as a symptom of broader gender inequalities, and is an issue to those concerned with gender stereotyping, because those that do own mobile phones encounter more gender stereotypes through sharing of digital content and images.

Schools and the post-secondary sector continue to challenge researchers in the slow uptake of teaching/learning technologies and practices. Global investment in learning technologies in schools has been initiated by many governments, including the UK ($2.5 billion GBP in 2008–2009), USA ($10.7 billion in 2009), and New Zealand ($410 million annually on infrastructure); yet, ICT adoption in education has lagged far behind that of the business sector (Nut, 2010, in Buabeng-Andoh, 2012). Recent research studies continue to highlight the difficulties that teachers face when using ICT in their daily educational practices (Vrasidas, 2015; Ward & Parr, 2010; Wastiau et al., 2013). Personal characteristics such as educational level, age, educational experience, experience with the computer for educational purposes, attitude toward computers, and gender can influence the adoption of a technology (Schiler, 2003). Among the factors that influence successful integration of ICT into teaching are teachers’ attitudes and beliefs toward technology (c.f. Keengwe & Onchwari, 2008; Teo, 2008). Bachmair, Pachler, & Cook (2011) warn that “fossilized” practices of schools militate the opportunities for learning as meaning-making, or situated learning, afforded by mobile technologies. For example, in one study, 363 teachers were assessed for their perceptions about approaching technology. Results indicated that teachers who embrace creative teaching methods tend to have higher positive attitudes toward technology use in the classroom. Similar results have occurred in studies of mathematics teaching and innovation (Holden & Rada, 2011).

While recent research shows that teachers with a positive attitude toward ICT are much more likely to use ICT in their teaching and for students’ learning, the implementation of ICT in teaching is also influenced by social norms and expectations (Gardner & Davis, 2013). Thus, according to Fransson (2016), who explores the notion of “dilemmatic spaces” in relation to social media, “understanding the everyday practices in which teachers try to manoeuvre between the expectations of others and their own beliefs, concerns, emotions and knowledge about the advantages and disadvantages of using ICT for teaching and learning would seem to be vital" (p. 186).

It appears that a teacher's sense of control is related to their digital competence, but there are differences in relation to gender and the use of ICT in different school subjects (Vrasidas, 2015). The research is mixed, with some studies finding no significant differences in teachers' attitude toward technology adoption with respect to their gender (Anduwa-Ogiegbaen and Isah, 2005; Gerlich, 2005; Rana, 2013; Verma & Dahiya, 2016) and others finding that males tended to show higher perceived efficacy in using ICT in learning and teaching, as opposed to females who believed that ICT could benefit mathematics pedagogy more (Ardies, De Maeyer, Gijbels, van Keulen, 2015; Chevers & Whyte, 2015; Lau & Yuen, 2013). Culture and place play a role, as do gender role expectations (Davis, 2008). For example, Kimbrough, Guadagno, Muscanell, and Dill (2013) found that women, relative to men, are connecting more and are using mediated technology to a larger extent, and men rate their technology self-efficacy higher than women. Performance expectancy, effort expectancy, social influence, perceived playfulness, and self-management of learning predict behavioral intention to use mLearning, and that gender differences moderate the effects of social influence and self-management of learning on mLearning use intention. For example, one study conducted in Saudi Arabia found a significant difference between male and female teachers in the use of ICT in language teaching and learning. However, the situation was unique, in that female teachers and students had their own campuses. Continuous breakdowns hindered the use of ICTs, as they had to wait for male ICT expert to fix the problem in the evenings. Further, the male teachers had twice as much access to computers as the females. This story reflects how context and culture significantly affect the ways that female teachers use ICT in their teaching (Saleh Mahdi & Sa'ad Al-Dera, 2013).

Likewise, the relation between students' self-efficacy and values and beliefs regrading ICT and teacher expectations, gender, and socioeconomic factors correlate with students' views of ICT for learning and confidence in their ICT skills (Vekiri, 2010). In an "increasingly marketized" educational sector, those from low socioeconomic backgrounds tend to rate their skills as lower than their peers, partly due to a lack of access to the technology (Pate, 2016). Females are more vulnerable than males to all these factors. Research before 2000 revealed that male teachers used more ICT in their teaching and learning processes than their female counterparts, with female teachers reporting lower confidence and capability (c.f. Jimoyiannis & Komis, 2007; Kay, 2006; Markauskaite, 2006; Wozney, Venkatesh, & Abrami, 2006). However, more recent studies have found that the situation is changing and that, in fact, a greater number of female than male teachers used internet and web 2.0 technologies in their classrooms (c.f. Breisser, 2006; Yukselturk and Bulut, (2009). While male teachers report higher levels of experience, ability and confidence using computers in education, after training and implementation of ICT infrastructure, there was no difference between female teachers and their male peers (Kay, 2006).

Self-Efficacy

Bandura (2001) is the researcher most associated with social cognitive theory, which highlights the interactions among personal factors, environmental conditions, and behaviors. A key construct grounded in this theory is self-efficacy, which refers to an individual's belief in his/her capability to organize and implement actions to reach a certain level of performance. The concept of self-efficacy can be defined along two lines: (1) as the judgments each individual makes about his/her own abilities; based on these judgments he/she organizes, performs, and assesses activities to achieve desired outcomes, and (2) as one's beliefs about the ability to carry out the activities at the required performance level required by expected situations (Aguirre Chavez et al., 2014). Self-efficacy is a significant factor in one's performance at school and work because it affects one's goals, values, motivation, and perceived obstacles in the social environment; higher self-efficacy results in higher expectations for and beliefs in one's ability to achieve success.

Self-efficacy beliefs are influenced by a number of different sources, including social modeling, but with previous performances the main source of influence. The experiences of those perceived as having similar attributes, for example, gender, can be powerful sources of self-efficacy information (Usher & Pajares, 2008). Teaching self-efficacy has been typically described in terms of preparation, delivery, and assessment (Hemmings & Kay, 2009). A large literature base explores the effects of gender on self-efficacy; the interest here is whether gender-related differences in self-efficacy are significant for purposes of the design of learning environments and activities. For example, Hemmings and Kay (2009) tried to determine gender patterns in Twitter use among assistant, associate, and full professors in Australian universities, and found that in the lower ranks, Twitter use was consistent among male and female faculty. Similarly, while Aguire Chavez and others (2014, who used the "Self-Efficacy Academic Behaviors Scale," a 13-item scale, with 1995 university undergraduates at a Mexican university, found significant global gender differences in the communication, attention, and excellence variables. Women consistently scored higher in perceived, desired, and reachable self-efficacy, but lower perceived self-efficacy improvement possibility on the excellence scale, suggesting that the women showed a greater need and lower possibility for improving self-efficacy. The authors conclude that that any mediation designed to improve perceived self-efficacy should take gender into consideration, particularly in the Mexican context where few studies of this nature have been completed. In other words, the sociocultural context is a significant factor in the development of self-efficacy on various scales.

Looking for influences on self-efficacy, a study of how gender and gender–personality interactions separately affect self-efficacy, conducted with business students at a Norwegian university of science and technology, found that female students had significantly lower self-efficacy levels and self-efficacy strength than their male peers (Fallan & Opstad, 2016). However, personality effects varied, suggesting that the notion of gender-based self-efficacy alone is too simplistic. The participants completed questionnaires based on Meyer-Briggs Type Indicator

(MMBTI)) and questions about their perceived self-efficacy in a "Principles of Economics" course. The authors concluded, "the general conclusion of lower perceived self-efficacy level among female students does only include those having NF (intuition/feeling) and NT (intuition/thinking) temperaments…(and) self-efficacy strength is only affected by females having NT and SP (sensing/judging) temperament" (p. 40). NF temperaments tend to be sensitive to hostility and conflict, prefer a democratically run classroom with bountiful interaction with instructors and peers, collaborative rather than competitive group work, pedagogical approaches using class discussions, case study assignments, and paper/essay assessments. NF learners are motivated by personal recognition and approval on papers or tests rather than good grades (Fallan & Opstad, 2016). Many studies on the preferred learning styles of females support this description of classroom culture (c.f. Sanders' overview, 2007).

By contrast, Gunn and others (2002) found gender differences in the self-reported levels of confidence, the ability to work successfully with technology, the use of support systems, and different patterns of interaction. Irani (2004) reported that female learners felt frustration, particularly because of lacking support in technology-related tasks, such as completion of computer programming tasks. The root cause gender disparity in computing science and practice may be attributed to the mainstream social construction of computing-related identities that discourage or limit female participation (Kaplan, 2014). Mikk and Luik (2005) analyzed the perceptions of adolescent girls and boys regarding the use of electronic textbooks and found that "electronic textbooks with a high complexity of navigation and design of information endanger the learning efficiency of girls" (178, in Richter & Zelenkauskaite, 2014)); Yukselturk and Bulut (2009) found "test-anxiety" to be significant variable for female learners. Richter and Zelenkauskaite (2014) also found cultural differences in learner perceptions related to gender-related fairness regarding teacher treatment after completed tasks in general, and particularly after failed tasks using technology. For example, German and South Korean learners perceived gender-related lack of fairness, while Ghanian participants perceived a "higher divergence between the genders was found regarding the treatment after failing a task but both groups expressed a positive impression of fair treatment" (p. 10). The authors concluded that gender-related differences in perceptions of education might be quite significant and "need to be considered in the educational design to reduce conflicts in educational scenarios and support students to keep their motivation on the highest possible level" (p. 10).

Self-efficacy can be affected by symbolic modeling, such as those in the media, and verbal and social persuasions, such as encouragement from teachers, parents, and peers. For example, Kekelis, Ancheta, Wepsic & Heber (2005) found that American parents, especially white and high-SES parents, were found to give less computer-related support to girls than to boys. Usher and Pajares (2008) found that it may be easier to undermine an individual's self-efficacy through social persuasions than it is to enhance it. This is relevant to the messages females receive about their abilities and future in math-related subjects and careers, such as engineering or IT. Self-efficacy is also affected by emotional and physiological states, such as high anxiety and stress. A lack of confidence in one's abilities may lead to a false interpretation of anxiety as a sign of incompetence. Further, learners tend to trust assessments of their ability made by someone they trust, or that is seen to have power and influence. Garber (2009) reminded researchers "in the tendency to gender the disciplines…the quantitative social sciences have sometimes been stereotypically regarded as 'masculine', serious, and hard…(and so) a belief develops in a class of persons, based on perceived inferiority: another class of persons, already more socially or politically powerful and more highly esteemed, is thought to possess the real thing… that this structure of thinking that dominates much of academic life, both within and among the disciplines…will not strike many as astonishing" (p. 69). This plays out as a significant gap between female and male levels of self-confidence in using computers, which may explain why male students are five times more likely to pursue a career in computer programming compared to females.

Cultural Differences

Gender differences in self-efficacy have some cultural basis, although in most cultures where research has been conducted, the results hold. For example, Viekiri and Chronaki (2008) found that in a study of 340 Greek elementary school students, there were significant gender differences in frequency and type of computer use. Furthermore, boys reported more perceived support from their parents and peers to use computers and more positive computer self-efficacy and value beliefs than girls. A GSMA (2013) survey provided a detailed picture of children's (aged 8–18 years) mobile phone behavior and gender differences across five countries: Japan, India, Indonesia, Egypt, and Chile. Gender differences were found with boys' higher use than girls' in Indonesia, India, and Egypt, the opposite being true in Japan and Chile. In this study, girls used health apps considerably more than boys; no gender difference was found when examining confidence and insecurity In Peru, efforts have been made to enhance the use of mobile phones in formal education (Barkham & Moss, 2012).

Valderrama-Bahamondez, Kauko, Jonna, and Schmidt (2011) reported on adoption of mobile phones in the 4th–6th grades in Panama, finding that boys were faster to adopt mobile technologies and explore more functionality, while girls took more time to familiarize themselves with the phone itself, perhaps choosing to explore the social aspects first. In this study, girls seemed to maintain a better focus on the learning activities using the mobile phones, suggesting different adoption and exploration strategies that are important to keep in mind when designing tools for mobile learning.

The impact of gender on learner's participation, motivation, and achievement in mobile game-based learning (GBL) in older children (aged 9–10 years) in Taiwan was analyzed in an ecological game. The findings showed that the girls asked fewer questions and spoke less than the boys, but no gender difference was observed in achievements and motivation. The authors of this study concluded that integrating mobile technologies and game design into classroom instruction may reduce the gender gap in learning participation in a traditional classroom environment, although they observed a gender difference in self-confidence pertaining to mobile technology use (Jung-Chuan, Jeng-Yu, & I-Jung, 2011).

In developing countries, the "Jokko Initiative" (Senegal), "Project ABC" (Niger), the "Somali Youth Livelihoods Project" (Somalia), "Nokia Life Tools" (Nigeria), and "M4Girls" (South Africa) are interventions using mobile devices to teach literacy, numeracy, maths, and/or employability skills and provide learning opportunities for people, who may not have been able to access formal education opportunities, primarily women (Zelezny-Green, 2012). In India, cellphones pre-loaded with applications that target English as a Second Language were used in a project with rural children (aged 7–18 years), showing a reasonable level of academic learning and motivation, although gender differences in attitude remained a challenge. Finally, it was found that gender attitudes remain a significant challenge (Kumar et al., 2010). However, Mobilink, a basic literacy program in Pakistan, was quite successful once parents and community leaders became less resistant to the idea of allowing girls to have mobile phones.

In Africa, girls remain marginalized. Chikunda and Chikunda (2016) share that every country needs "to harness the intellectual and scientific capacity of both men and women for sustainable social, ecological and economic development. Yet, SMTs constitute the areas within the educational system where gender disparity is greatest, in several of the poorest countries of the world" including Zimbabwe (p. 11). Even though the Zimbabwe National Gender Policy (2004) specifically identified strategies such as "promote and encourage girls to take on science, mathematics and technology at all levels of education and introduce gender awareness programmes to pre- and post-training teacher courses" (p. 13) patriarchal values embedded in the hidden curriculum remain, such as the gender typing of school subjects and occupations, low expectations of female teachers for female students, undervaluing of female students' work, as well as "mocking, humiliation, verbal abuse and the unnecessary ridicule of girls" in STEM subjects in school, cited as some of the prevalent practices that bolster patriarchal values by Mutekwe and Mutekwe (2012) in Chikunda & Chikunda (2016).

Because informal learning activities based on mobile technologies are more accessible for girls who are excluded from formal learning environments, cellphones may support better outcomes such as life skills, health care and personal development. In all these studies, parental support and, to a lesser extent, peer support were the factors more strongly associated with boys' and girls' computer self-efficacy and value beliefs, while home computer access was not related to students' motivation, highlighting the role of socialization in the gender gap. Social practices continue to communicate gendered expectations to boys and girls. Also, the preponderance of males in the academic field of computer science and the resultant male dominant culture in this area of study has been identified as one of the barriers that female computer science undergraduates face (Rajagopal & Bojin, 2003).

Sharpe's (2014) review of learner attributes reflects growing interest in "learner experience research" within the field of learning technology. Learner experience approaches use "qualitative, exploratory and participatory research methods to elicit learner experiences and generate rich descriptions which foreground learners' perspectives, beliefs and behaviors" (p. 126) while acknowledging that contextual factors such as course design (Kirkwood & Price, 2005) and sociocultural influences shape learners' use of technology. Being skilled includes issues of voice, identity, and awareness of self-presentation. Sharpe's (2014) review includes connectedness; confidence, including included digital identity and privacy; self-efficacy; and collaborativeness as key attributes, although females tend to underestimate their "abilities" self-reporting confidence, which does not relate to appropriate technology use (Masterman and Shuyska, 2012, in Sharpe, 2014).

Farah's (2011) doctoral research revealed that gender may play a role in influencing one's technology self-efficacy. The self-efficacy survey results showed that males, overall, had higher technology self-efficacy than did females who responded to the survey. An overwhelming percentage, 81.8%, of male survey respondents scored in the very high range, while only 16.3% of female respondents scored in the very high range. This finding indicates that males may tend to have higher technology self-efficacy than females. (107). Jun and Freeman (2010) add that individuals learn society's gender role standards and expectations, and they accordingly develop attitudes and conduct behaviors that society deems gender appropriate. If females perceive that society expects them to know and use less technology, then they are more likely to adopt this same expectation for themselves. In another study by Mackay and Parkinson (2010) involving South African technology teacher trainees, they too found that females had lower self-efficacy than did males. Beyond society creating norms or expectations that may play a part in the differences between females and males in regard to self-efficacy, so too might the different mindsets each gender has when they are self-reporting their self-efficacy, as was suggested by Schunk and Pajares (2002): "A second factor that may be responsible for gender differences in self-efficacy and in confidence to use self-regulated learning strategies is the tendency of boys and girls to respond to self-report(ing) instruments with a different 'mind set'…boys tend to be more 'self-congratulatory' in their responses whereas girls tend to be more modest…boys are more likely to express confidence in skills they may not possess and to express overconfidence in skills they do possess" (p. 119).

Culture and Beliefs About STEM

Cultural beliefs about superior masculine abilities and skills, girls and women tend to judge themselves by a higher standard, assess their abilities lower, and show less interest in pursuing a related career (Correll, 2004). This relates to self-efficacy because we often use stereotypes as "cognitive crutches," especially in areas where we do not know how to assess our performance. Correll (2004) refers to research specifically in math classrooms that shows when a girl believes that most other people in the environment think boys are better than girls at math, even if she does not herself believe that, the thought is going to affect her, even if she does not believe it herself. In other words, what other people think is what matters. As evidence, Correll (2004) points to the damage done by the 2005 comments of Larry Summers, the former president of Harvard, when from a position of power and influence he publicly doubted that women could succeed at the highest levels of science and engineering: not in every domain, just in masculine domains.

Pajares (2005) found that gender differences in self-confidence in STEM subjects begin in middle school and increase in high school and college, partly because boys develop greater confidence in STEM through experience developing relevant skills. But, gender differences in self-confidence start to disappear when variables such as previous achievement or opportunity to learn are controlled. In other words, students who lack confidence in their skills are less likely to engage in related tasks, giving up more easily in the face of failure. Good, Rattan, and Dweck (2009) showed that when a girl believes she can become smarter and learn what she needs to know in STEM subjects, as opposed to having innate ability, she is more likely to succeed.

Higher self-efficacy related to mathematics has been shown to increase the odds of enrolling in high school calculus and choosing a STEM major in college, including computer science. These findings suggest that cultural beliefs about the appropriateness of one career choice over another can influences self-assessment and may partially account for the disproportionately high numbers of men in technology-related professions, over and above measures of actual ability (Correll, 2004). In addition, Lubinski and Benbow (2006) found that girls who excel at math tend to score highly on measure of verbal abilities; combined with societal expectations about masculine and feminine domains, they tend to consider future education and careers in the humanities or social sciences, rather than science and engineering fields. One possible explanation for this lies in the well-documented gender differences that exist in the value that women and men place on doing work that contributes to society, with women more likely than men to prefer work with a clear social purpose (Eccles, 2006; Lubinski & Benbow, 2006; Margolis and others, 2002), whether the difference is innate or socialized. If society does not view formal learning that leads to credentials in STEM careers being of direct benefit to society or individuals, these paths often do not appeal to women (or men) who value making a social contribution (Diekman, Brown, Johnston, & Clark, 2010; National Academy of Engineering, 2008). Zeldin, Britner, and Pajares (2008) found that "social persuasions and vicarious experiences" were the key to women's self-efficacy beliefs in male-dominated domains, while the self-efficacy beliefs of men were created primarily through their interpretations of their ongoing achievements. The authors concluded, "women…rely on relational episodes in their lives to create and buttress the confidence that they can succeed in male-dominated domains**"** (p. 1039). In another study, Diekman and others Diekman et al. (2010) found that STEM careers, relative to other careers presented, were perceived to impede communal goals, and that communal-goal endorsement negatively predicted interest in STEM careers, even when controlling for past experience and self-efficacy in science and mathematics.

Discussion

What lessons can we take from this, sometimes, contradictory research? First, when cultural beliefs support male superiority on a task, women tend to use a higher standard to judge their own abilities. However, if no gender difference in ability or performance is suggested, men and women and men tend to assess themselves by approximately the same standard. This suggests the important influence teachers, parents, and peers have on the development of self-efficacy (Hill, Corbett, & St. Rose, 2010; Vekiri, 2010). The research of Michie and Nelson (2006), and Tomte and Hatlevikb (2011) supports this view, finding that traditional work role expectations concerning women's efficacy for careers in IT still persist, affecting self-efficacy. Ceci, Williams, and Barnett (2009) conclude that "evidence for a hormonal basis of the dearth of female scientists is weaker than the evidence for other factors," such as gender differences in preferences and sociocultural influences on girls' performance on gatekeeper tests (p. 224).

Research related to self-efficacy and related factors such as motivation and test anxiety have shown these issues amenable to interventions that have been designed and evaluated. For example, in the "Bring Your Own Device" approach, utilized in education and industry, learners are invited to bring personal mobile learning devices into the learning environment. While disparities exist by socioeconomic status and culture, eighth-grade females enrolled in math classes using MLDs scored 65.95 points higher on average on an annual assessment compared to their peers who did not use MLDs in their classes (Cristol & Gimbert, 2013).

Grimus (2014) also saw that the increasing adoption of mobile devices was helpful for girls to break through the perception of technology as a "male thing." However, while both males and females use mobile devices such as smartphones, parents and teachers do not point out that girls as well as boys can create sophisticated applications with them. One program developed for teenagers in the UK ("Apps for Good," http://www.appsforgood.org/) mitigates against this notion by promoting creative learning programs, such as mobile app development, to build skills and confidence of young people aspiring to become technology experts. This is consistent with findings that females may prefer to design creative activities over learn how to program.

Finally, challenges observed in education in developing countries need similar research in the developed world with regard to children from marginalized groups, particularly girls and immigrants, who live in extreme poverty, in slums, in remote communities, or are from ethnic minorities.

Gender and Generational Differences

While the prevalence of social media is having a significant impact on how we socialize, work, and learn, young people use new technologies for social ends that are much the same as for earlier generations using old technologies. For example, Baby Boomers talked on landlines, just as this generation uses texting, blogs, and social media sites. They signal in-group identity, not by handshakes or adornment, but by using language creatively while texting. Herring (2008) observes that the ends are more important than the technological means, that is, the focus is on social functionality rather than on the technologies themselves. The difference is in the scope of participation, from one-to-one, to one-to-many, or many-to-many. Personal diaries were at one time fiercely protected from prying eyes, now little is private.

Much has been made of a "generational digital divide" as it pertains to media consumption and communications. The divide refers to millennials (so-called digital natives), on the lower end, and older learners (so-called digital immigrants), the generations born from the 1940s (or earlier) to 1982 (c.f. Tapscott, 2009). Because digital natives have one foot in the TV world of earlier generations and the other in the digital world, Susan Herring (2008) maintains that the first true digital native generation has yet to be born (perhaps it will be Generation Z). In a critique of the generational digital divide, Herring suggests that millennials be viewed as a transitional generation astride the predigital and digital worlds, a world that is still controlled by older adults. Calling for a paradigm shift, she proposes a research agenda toward a more nuanced understanding about how young people use and express themselves through new media, focusing on identity formation (c.f. Jenson, Dahya, & Fisher, 2014). Identity formation is clearly related to gender identity and its development in new media environments.

Judge and Tuite (2017) make this point strongly with regard to media education and youths' aspirational identities that "are tied up in visions of themselves as future media professionals facing an uncertain employment future in the Age of Austerity" (p. 46) in Ireland, where their study of students' work in media studies over a 12-year period (2003–2014) in a university setting is located. Referencing the work of Wajcman (2000), Hargittai and Walejko (2008), and Clegg (2010), Judge and Tuite (2017) identify issues of power, control, privilege, gender, and social inequality "when three powerful industries comprising computing, telecommunications and the media amalgamate." They were particularly interested in how gender construction, representation, and inequality present themselves across all three industries, in that they are male-dominated and embody a masculine identity. As we have seen, the masculine culture of technology, through its symbols (language), metaphors, expectations, and values in all stages at which it is encountered, has sustained the alienation of girls and women from early school preparation to structural barriers to full participation in STEM fields (c.f. Wajcman, 2007). Judge and Tuite point out that structural barriers become systemic, as underrepresentation in these industries perpetuates itself and results in "a big opportunity miss for gender and ethnic diversity in the industry" that would provide different perspectives in social issues that are the basis for storytelling. Research on the new digital media sector confirms that "despite its cool, creative and egalitarian cultural economy image (there is continuity) ...with the old economy in terms of some enduring gender inequality and discrimination practices" (Banks & Milestone, 2011, in Judge & Tuite, 2017, p. 30). However, a fair caution in this type of research is to avoid normative readings of femininity and masculinity, taking into account the ways in which context, culture, knowledge, and prior experience influence technological competence (40). We can observe this in studies of girls and women who have been given an "equalizing" amount of time to "tinker" with technology (c.f. Sorby, 2009).

Box 4 Male and Female Choices in Multimedia Education
Judge and Tuite (2017) studied the multimedia projects created by students' final-year multimedia productions over a 12-year period (2003–2014) at Dublin University. They analyzed the gender distribution of production teams, and the content and media decisions for finished productions by genre, media type, audience, and purpose, through the lens of gender. Overall, they found that the productions were influenced by "multilayered voices encompassing internal, external, personal, public and institutional forces…both overt and covert, such as the curriculum and the academy" (p. 48), drawing attention to "the institutional setting and how the power dynamics within can inform what can be produced, by whom and how it is shaped" (p. 48). The authors discovered that student-produced new media reflected many gendered qualities, especially regarding the type of media to produce, the choice of audience to talk to, and the composition of groups. For example, as the female-only groups self-selected administrative or caring roles rather than at the cutting edge of technology and creative practice. Groups taught by a female instructor produced different artifacts than those taught by a male, or mixed-sex teams of instructors, resulting in more "educational" artifacts such as eLearning and documentaries, geared toward younger audiences. Judge and Truit (2017) speculated that such products are framed by a sense of 'others' rather than a sense of 'selves', reflecting students' desires to produce something useful for others (a gendered trait). They also found the inclination of female students to work with print media and not just online media of interest, perhaps reflecting the role that books play in the lives of young girls. The researchers were apparently *not* surprised to find that that males (in a disproportionate number of male-only groups) dominated the UI/UX and storytelling spaces. Argued that projects such as

> Judge and Truit concluded that elements of the "hacker culture" and women's dislike of the 'tinkering' (Sax, Jacobs, and Riggers, 2010, in Judge & Tuite, 2017) aspects of digital media, "which has traditionally acted as barriers to women pursuing computer studies, are clearly in play here, as the UI/UX projects are more technically demanding involving programming" (p. 46). They compare the self-selection of student teams to the formation of male subcultures (i.e., "old boys network") that act as "gendered social enclosures" that create barriers for women in such creative and technical fields. The authors ruefully ask if one should be surprised at this finding, as men outnumber women 3 to 1 in family films on screen (which has remained unchanged since 1946), in front of and behind the camera, so when it comes to creating stories and using the technical tools to do so, female students see themselves as less capable and less creative, with "less valuable stories to tell" (p. 47).

A robust Information Society is considered to be economically more competitive, and fosters greater social cohesion, participation, and control of citizens (Aroldi, Colombo, & Carlo, 2015). Accordingly, the EU sponsored the SHARE study (Survey of Health, Ageing and Retirement in Europe), a "multidisciplinary and cross-national panel database of micro data on health, socio-economic status and social and family networks of more than 120,000 individuals aged 50 or older," across 27 European countries, and Israel (http://www.share-project.org/home0.html).

In the fourth wave of the study (2010–2011), 8639 individuals, aged 50 years and over, in Portugal and Estonia, were surveyed. These two countries were chosen as they had different welfare systems and relevant public policies. Previous studies have identified senior citizens as very vulnerable to the digital divide. Digital access divide is one factor among many: other factors include types of use of technology, knowledge about Internet features, and understanding of and ability to access information online. Studies of older age groups have shown, in general, that certain sociodemographic characteristics of individuals (age, gender, education, mental and physical health status, mobility, and income) condition the use of technology (Silva, Matos, & Martinez-Pecino, 2017). While earlier research concluded that age was a singular factor in the digital divide, SHARE participants revealed the reflection of inequalities in social structures was related to the economic, political, historical, and social characteristics of the respective countries in the study. In general, however, the group of Internet users was mainly composed of males (59.30%) while the group of nonusers was essentially composed of females (Silva et al., 2017). The Internet users group also reported having more years of schooling and fewer financial problems. Socioeconomic status was related to level of education and limited pensions (an historical political artifact), factors related to gender. However, the study suggested that the number of females using the Internet tends to increase, moving toward growing gender parity (c.f. Fox, 2004). SHARE included 16 European countries in the survey, finding that macro-social variables such as public social policy (e.g., broadband access) may have the most influence on the e-inclusion of seniors. For example, Silva et al. (2017) point to significant investments made in Portugal over the past decade in technology programs, adult education, the provision of specific IT training by senior citizen universities, parish councils, and NPOs, often available free of charge, and the creation of public spaces for free Internet access; as well as incentives to use the Internet such as banking and access to eGovernment.

Discussion

With regard to social media, designers and educators are experiencing a "dilemmatic space" (Fransson, 2016), while those in the user experience area are challenged to keep up with gender, generational, and cultural differences. Describing the digital dilemmatic space, Fransson (2016) "offers ideas about how to relate to a digital society in a way that on the one hand takes its point of departure in the options, risks and dilemmas of a digitised society and the use of the Internet, but that on the other hand also emphasises relational aspects, positions and the dilemmas of dealing with the different values, norms, tasks, options and loyalties that can emerge in a digitised society" (p. 187). Uncertainty is then a key component in constructing dilemmas. Exploring Fransson's (2016) dilemmatic space suggested a connection with Mezirow's theory of "disorienting dilemmas," which may lead to perspectives transformation. In other words, experiencing learning in a dilemmatic space may encourage transformative learning.

For example, social networking sites such as Twitter, Facebook, or LinkedIn are dilemmatic spaces because while participation may help seniors actively engage with members of their own or different communities across time and place, they are also spaces of miscommunication, misinterpretation, and harassment, that is, risk. Issues like these present challenges to designers of online learning, as one example.

Online access, and the digital access divide, is reflected in cultural differences no matter the region, and women are consistently more social on the Web than their regional, male counterparts: in Asia Pacific, Europe, and Latin America, women are underrepresented online. India and Indonesia are two countries where women's presence online is very low compared to men. Globally, women spent an average of 16.3% of their online time on social networks in April 2010 compared to only 11.7% for the men (p. 9). Apparently, the over-45 years-of-age segment of women drives the greatest proportion of growth for social networking; in the over-55 years of age group, women have embraced social media by 10 percentage points over males (p. 10). In the 15–24 age range, social media use is similar among males and females, although the search behaviors and interests differ, with males more inclined to post on sites such as Twitter, while women are more inclined to follow conversations. The rates of adoption of social media in Singapore and Australia were the highest. On average, males conduct more searches per user than women. In all regions, males are the heaviest users of mobile technologies, owning more "smartphones" and subscribing to more services. One possible explanation for this is that men tend to be higher earners than women, and employed in workplaces at higher status levels, affording them the opportunity to purchase, thus affording them the ability to purchase the technology and enjoy employer-paid services.

For the next section, consider the issues of gender, culture, and place in a digitized world as a case of dilemmatic space, acknowledging the processes of power, positioning, and negotiation in the work involved in navigating access and equitable participation in the online world.

From Digital Access Divide to Social Inclusion: Gender and Digital Fluency

The phrase digital divide was coined in the 1990s referring to the divide between those who had access to ICTs and various forms of digital technologies and those who did not. In other words, digital divide was ununderstood to mean "digital access divide." Determinants included financial status, household income, educational level, type of occupation, and geographical location. In this definition, or understanding, communities with lower educational attainment, for example, which is often tied to lower financial status, would likely have limited or no material access to ICTs and digital media compounding the effect (Adhikari, Mathrani, and Scogings, 2016, p. 325). Today, "digital divide" has new meaning. It refers to the gap in the intensity and nature of IT use rather than to the gap in access to it. For example, research consistently indicates that adult females are more likely to use the Internet's communication tools, whereas adult males are more likely to use the Internet for information, entertainment, and commerce (Jackson et al., 2008).

New data released by ITU, the United Nations specialized agency for information and communication technologies (ICTs), show that 830 million young people are online, representing 80% of the youth population in 104 countries. ITU's "ICT Facts and Figures 2017" also shows a significant increase in broadband access and subscriptions, with China leading the way.

This annual release of global ICT data shows that youths (15–24-year olds) are at the forefront of Internet adoption. In Least Developed Countries (LDCs), up to 35% of individuals using the Internet are aged 15–24, compared with 13% in developed countries and 23% globally. In China and India alone, up to 320 million young people use the Internet.

Since the world is fluid and continuously transforming, a shift in the digital divide research has been occurring. For example, the focus is shifting from institutions to the appropriate use of technology, for example, as in participation and meaning-making, to the individual, facilitating individuals to make more personal use of flexible and mobile platforms in daily as well as constrained contexts. Technological advances in the past decade have highlighted the use of social media access and use, as well as ubiquitous cell-phone usage for gaming and other applications. This increase in technology use focuses attention on the sociocultural contexts in which it takes place; issues of a social digital divide continue to reflect challenges related to race, age, gender, and geopolitical location. We have seen that the manifestations of this divide are clear now and have been since the 1980s, in the underrepresentation of women in the ownership and use of computers, uneven demographics in high school and university STEM classes, and in the persistence of social stereotypes (c.f. Pinkard, 2001; Mitra, 2001).

Access as a Human Right

The "Human Rights, Big Data and Technology Project" at the Human Rights Centre of the University of Essex submitted a comprehensive report, *Ways to Bridge the Gender Digital Divide from a Human Rights Perspective* (2016), in which they stated as follows:

> While…technologies offer unprecedented opportunities for advancement in areas ranging from education to political participation and employment, they have also been pinpointed as a key factor in social and economic disparities. Existing inequalities are reflected in

> discrepancies in the access to and use of ICTs, thereby transposing offline divides into the digital space. Due to the negative impact of lack of free access to use of and benefit from ICTs, the digital revolution risks significantly amplifying the gender divide across different social and economic groups. This constitutes a barrier to the emergence of an equitable information society by perpetuating, and even exacerbating, gender inequality, gender inequality being both the cause of and aggravated by the gender digital divide…. Throughout the world, economic, social and cultural obstacles prevent or limit women's access to, use of, and benefits from ICTs, a phenomenon referred to as the gender digital divide (p. 2).

The report lists a number of impediments to ICT access and effective use, including the distinct socioeconomic disadvantages faced by women leading to cost barriers; influences of physical and social/cultural impediments; geographical isolation and poor technological infrastructure; lack of content relevant to their experience, context and language; filtering policies that block access to health and sexuality information (e.g., LGBTQ+ issues) affecting women's health and reproductive rights; an education gap resulting in lower levels of literacy, numeracy and technological skills; a hostile and unsafe online environment marked by negative stereotypes, attitudinal biases linked to conservative gender roles, harassment, and hate speech. In addition to preventing women from taking full advantage of education and work opportunities, these barriers may result in women's lower presence in online political discourse.

The report suggests an intervention to the digital divide challenge based on human rights, referencing a number of related international declarations: the "International Covenant on Civil and Political Rights" (ICCPR); the "International Covenant on Economic, Social and Cultural Rights" (ICESCR); the "Beijing Declaration and Platform for Action"; the "Universal Declaration of Human Rights" with the sustainable development goal (5) on gender equality outlining targets for every country to make gender equality a reality; the 2003 "Declaration of Principles on Building the Information Society" adopted by the World Summit on the Information Society (WSIS); and "The Tunis Commitments and the Tunis Agenda" (2005), among others. The authors conclude that the "implications for States are clear. Ensuring equal access to the benefits provided by ICTs is an important part of their fulfilling their obligations under international human rights law, including achieving full respect for women's human rights."

Referring to the role played by the private sector in women's rights to access, the "UN Guiding Principles on Business and Human Rights" (UNGP) declared that corporations are responsible to respect internationally recognized human rights, addressing negative impacts when they occur, and implying that international businesses could contribute to the education gap in regions in which they are conducting business.

"It is society's dilemma that the path to computer efficacy is more difficult for the poor, for ethnic minorities and for women" (Wilson, Wallin, & Reiser, 2003, in Cooper, 2006, p. 320). A digital divide for gender has an impact on if and how women are reaping the benefits of a society based on ICT use, as well as affecting the economy itself. Research indicates that media use habits are formed early in life, foreshadowing IT use in adulthood. Children's IT use predicts their academic performance: those who had been using IT longer had higher grades in school than those who were more recent users. The longer an individual has been using IT, particularly the Internet, the more intensely it is used and the more diverse the user's activities become. For example, the development of Internet skills, such as navigational skills, as well as motivation, is directly related to the amount of time online. This outcome is correlated with parents' attitudes and socioeconomic status. Low-income children, especially girls, used the Internet less often than Caucasian children (Jackson et al., 2008).

Although, while Jackson and others (2008), in their study of race and gender differences in the intensity and nature of IT use, found that white children had been using a computer longer than African American children and that African American males used computers and the Internet for less time when compared to other groups, they also found that females were more likely than males to use the Internet for academic purposes, and for communication purposes. Females were more likely than males to instant message with friends, create documents for school, save images/graphics, take a survey online, take a test online, read mailing list messages, and use e-mail. In fact, African American females were found to use the Internet more intensely and in more diverse ways than any other group, whereas African American males used it less intensely and in fewer ways than any other group. Other race by gender interactions indicated that African American females were most likely, and Caucasian American males least likely, to search for information about health, diet, and fitness. All females were most likely compared to all other groups to search for information about depression, mood, and mental illness; to search for news and current events; and to exchange photos. However, African American males lagged behind all other groups in their IT use except in online gaming. In other studies, females of color were subject to the "double discriminatory burden of femaleness and minority status" (Sanders, 2007). Morrell and his colleagues (2004) found that a day-long Saturday program for middle school girls had a stronger effect on girls of color than white girls, suggesting that the white participants had had more exposure to computers before joining the activity (Morrell et al., 2004). In another extracurricular program, Techbridge in California, girls self-segregated by race which generated racial tensions. Intervention activities revealed that it was noted that girls with lesser technical skills and lower self-confidence were at particular risk of dropping out from attempts to force them to cross racial lines (Kekelis et al., 2005).

While more current research suggests that the digital access divide, in terms of ownership, may be narrowing, Jackson and others (2008) suggest that the issue of Internet access remains hidden among higher usage of some ICTs by African American youth, who spend more time watching television, playing video games, and using a cell phone), two of which have been linked to negative academic outcomes (Rideout, Foehr, & Roberts, 2010). This highlights the challenge of Intersectionalities, where early access may lead to more positive outcomes. As white youth have been found to have earlier access, overall, than African American youth, the social digital divide may potentially contribute to long-term inequality in education and quite possibly psychological well-being (O'Neal Coleman, Hale, Cotten, & Gibson, 2015).

Digital Inclusion and Place

While global Internet use has increased – from 20.6% of the world online in 2007, to an estimated 47.1% in 2016 – it has been uneven both between and within countries. According to the World Wide Web Foundation (https://webfoundation.org/2016/10/digging-into-data-on-the-gender-digital-divide/), "One of the most pernicious aspects of the global digital divide is the digital gender gap and unfortunately, new data reveals that this digital gender gap is growing wider." In their report of October, 2016, *Digging into Data on the Gender Digital Divide*, the Foundation identified two noteworthy points to consider: (1). There is an urban–rural divide related to the gender gap in Internet use, and (2). Age is also a factor in the digital gender gap.

For example, in rural areas, the gender gap is higher in high-income countries (9.4%), whereas in urban areas, the gap is slightly higher (at 6.6%) in low- and middle-income countries. However, a survey of the ten low- and middle-income countries revealed that, in urban poor communities, women were nearly 50% less likely to access the Internet than men in the same communities.

The digital gender gap increases as age increases and is more significant in low- and middle-income countries. Among 15–24-year olds, the gender gap is 2.9% in low- and middle-income countries. But, when we consider age (i.e., age 75+), there is an average gender gap of 45.8% across all countries. Although age and location are certainly important factors (see Generational Divide, above), unequal access is also related to systemic and other sources of discrimination in society, such as patriarchal systems of power that may restrict women's access to technology through the gender wage gap, unpaid work and care, uneven and unequal access to education, and the so-called "triple burden" (i.e., the view of a woman's simultaneous responsibilities to her family, job, and community, c.f. Kramarae, 2001). Worldwide, there is a gender gap of 12% in male and female access to the Internet. This rises to almost 31% in "Least Developed Countries" (LDC). According to Irina Bokova, Director-General of UNESCO,

> Women are still left behind from the growth in mobile phone ownership, the most prevalent means of access to the Internet in developing countries. Mobile phones are important tools for enhancing the lives of women in low- and middle-income countries. They help women feel safer and more connected, save time and money, and access life- enhancing services such as mobile money, or potential education and employment opportunities (UNESCO, 2017a, p. 7).

Women's digital inclusion can help to catalyze broader gender equality in social, economic, and political dimensions – benefiting not only women themselves, but also their communities and the broader economy. Internet penetration rates are higher for men and boys than women and girls in all regions. While the Internet user gender gap has narrowed in most regions since 2013, the proportion of men using the Internet remains slightly higher than the proportion of women using the Internet in two-thirds of countries worldwide. In 2017, the global Internet penetration rate for men stands at 50.9% compared to 44.9% for women. The research of the International Telecommunication Union (ITU, 2017) has estimated that in low- and middle-income countries, there are 200 million fewer women than men who own a mobile phone, and that even when women do own a mobile device, they are less likely to use it for transformative services such as mobile Internet, further widening the divide (p. 6). The ITU concludes by warning readers that the digital divide will never close on its own because the root causes are driven by a complex set of social, economic, and cultural barriers, that is, structural inequalities. As women's digital access can contribute significantly to the global economy and society, formal educational environments, along with the corporate and government sectors, are implicated in targeted intervention including design research.

The Accenture "Digital Fluency Model" (2016) reflects the extent to which both men and women have embraced digital technologies to become more knowledgeable, connected, and effective, and examines the impact of digital technologies across women's entire career lifecycle. The authors surveyed nearly 5000 women and men in 31 countries to gauge their familiarity with digital technologies, seeking specifics about education and career choices, for example, whether they had ever taken virtual coursework through an online university, how they used digital collaboration tools for work, and whether their company increased efforts to recruit more women for senior management roles. They found that, while men outscore women in digital fluency across almost all of the 31 countries studied, the gap is narrowing. The study also found that digital fluency acts as an accelerant in every stage of a person's career, in education, the workplace, and especially as an individual advances toward leadership. Digital fluency supports better time management and enables greater work flexibility, from which women may derive greater value. Combined data from the ITU with the survey results revealed a "digital fluency score" for each country, suggesting how digital fluency might drive positive changes in women's education, employment experience and work advancement. The results are revealing of sociocultural norms and expectations, as well as political practices and, in some cases, are surprising. Overall, men scored better than women in three quarters of the surveyed countries.

For example, Japanese men outscored women in all metrics, including education, and Japan's advancement scores are among the lowest. India had the largest gaps in the overall score between men and women, and the lowest overall score of all the countries surveyed. Indonesia also scored low, affecting women's progress in employment. The largest gaps between the digital fluency of men and women appeared in Japan, Singapore, France, and Switzerland. Saudi Arabia and the UAE were the only countries that scored lower than India overall. What accounts for these gaps?

In over half of the surveyed countries, women attained higher levels of education than men. It appeared that digital fluency had a more positive impact on the education of women in developing countries than in developed ones: 68% of women in developing countries, to 44% of women in developed countries, believed the Internet was important to their education. Apparently, where men and women have the same level of digital fluency, women have achieved a higher rate of education. However, access to higher education in different countries reflects sociocultural practices.

The study also found that millennial men used digital channels for education and work at the rate of 80% to 75% for millennial women. All men were more proactive than women in learning new digital skills at 52% vs 45%. Accenture claims that the Digital Fluency Model "shows that nations with higher rates of digital fluency among women have higher rates of gender equality in the workplace" (np) identifying the USA, the Netherlands, the UK, and Nordic countries among the top performers on workplace equality.

Discussion

While digital access divide appears to be narrowing, at least in developed countries, gender differences are reflected in the nature of use of ICTs. For example, younger women were more likely to use social media to socialize, develop, or maintain relationships; seek health and beauty advice; and participate in online educational activities, younger men tended to use ICTs for gaming. Older women in certain geopolitical regions were not equally represented online. Developing countries continue to show gender disparities implicated in socioeconomic and political differences. A particularly interesting theory came from the analysis of data from 21 countries: women's ICT representation tends to be relatively high in countries that score low as liberal egalitarian societies (Charles & Bradley, 2005). They speculated that in countries where women have a freer choice of careers, gender stereotypes lead them to make stereotyped career choices, and that "[R]estrictive government practices that minimize choice and prioritize merit may actually result in more gender-neutral distribution across fields of study." They conclude that sex segregation in computing is linked to "deeply rooted cultural assumptions about gender difference" (Charles & Bradley, 2005, in Sanders, 2007, p. 9).

The global picture in 2017 has implications for educators and policymakers, particularly those of us working with adult learners, distance and online learners, and learners marginalized by race and socioeconomic status. For example, as many regions are increasingly invested in eGovernment, how can we encourage the participation of those without daily, personal access to the Internet? If women's participation in formal, and informal, educational opportunities improves the socioeconomic and health benefits of families, how can we compensate for constrained access to online learning environments? If the global economy depends on the full participation of women in STEM careers, how can we attract and encourage women into STEM-related programs, widen opportunities, and retain women in these sectors?

The next section follows on from this discussion of the digital divide, reviewing participation in social media platforms. Previous research in this area focused on computer-mediated communications (CMC), especially discourse patterns and characteristics of females and males. Because CMC was a mainstay of online programs, an understanding of these patterns was important not only to the design of learning activities, but also to the professional development and support of facilitators of online discussions. The advent of the "social Web," which encourages peer-to-peer and co-construction of content, has raised new questions about ethical behavior; safe online environments in which to learn; the role of teachers; the quality, source, and reliability of information; and the social effects of global, mostly unregulated access to social media platforms. Concern about gendered interaction continues, as do questions about political and economic contexts of use.

Gender Online: Social Media, Age, and Culture

The study of gender differences in computer-mediated communication (CMC), or online discourse, has a long history. The first viable asynchronous online discussions occurred in the 1990s; as early as 1991, Selfe and Meyer reported gendered power dynamics in an asynchronous academic discussion list, with men and high-profile members of the community dominating communication, even under conditions of pseudonymity. Subsequently, gender differences in public online discussion forums and chats showed males to be more assertive, self-promoting, rhetorical, argumentative, insulting, impatient, adversarial, sarcastic, and profane and females to be more accommodating, supportive, attenuating, courteous, affectionate, accepting of others' views, and upbeat (c.f. Cherny, 1994; Herring 1993, 2003a, Thomson & Murachver, 2001). Herring (2012) points out these online patterns reflected gender styles in spoken conversation (c.f. Tannen, 1990, 1994, 1996), and that "conventionally gendered ways of communicating are deeply embedded in people's social identities, and…differences tend to persist even in conscious attempts to manipulate gendered language" (Herring & Martinson, 2004, p. 444).

Herring also observes that, contrary to academic and public beliefs that these patterns are outmoded or disappearing as social media becomes ubiquitous, Kapidzic and Herring (2011) found similar message tones in a teenage chat room. The social exchanges initiated by males were significantly more aggressive, profane, and flirtatious than those of girls, who used more hedges and friendly phrasing and emoticons that represented smiles and good humor; were more apologetic; and thanked other participants for their messages.

Kapidzic and Herring (2011) conclude that the findings indicate that "despite changes in technology and purported feminist advances in society over the past 20 years, traditional gender patterns in communication style and self-presentation persist in CMC, at least in heterosexual teen chat sites" (39). The researchers suggest that patterns are perceived by the teens who employ them to serve useful purposes. In fact, "symbolic gender differentiation via language and images" are socially facilitative and aim to "heighten mutual…attractiveness in teen chatrooms, in which direct physical actions are unavailable, (and that) …what constitutes female and male attractiveness are not random; rather, they are ingrained in western society and reinforced by mass media representations" (Durham, 2008, in Kapidzic & Herring, 2011, p. 41). However, relatively little empirical evidence exists on "how people perform a different gender online, to what behavioral cues other participants attend in assessing others' real-life gender" and "the relationship among claimed gender, actual gender, and language use" (Herring & Martinson, 2004, p. 425).

Synchronous environments have been harder to characterize. Some early researchers contended that traditional gender binaries were blurring and breaking down due to the greater anonymity and "safety" afforded by text-based technological environments (c.f. McRae, 1996). Pseudonymous chat environments were thought to bring out the inherently fluid, performative nature of gender identity (Butler, 1990), in keeping with a trend toward the deconstruction of gender categories in postmodern society. For example, Gross (2004) found that male and female teenagers did not differ greatly in their online habits or behavior. These last observations raise an important issue, which is that times – and technologies – have changed since the gender and CMC research conducted in the 1990s. Herring describes the development of Web 2.0 technologies, with their convergence of multimodal, communicative, and collaborative features, which have given rise to massive social networking sites such as Facebook and weblogs, or blogs, incorporating asynchronous discussion forums, polls, testimonials; avatars, and personal user profiles, with photographs of self, friends, and family. These sites encourage the widespread circulation of real and fake news, popular culture sites, marketing, and cultural memes. Interestingly, on these sites, anonymity has given way to sharing, and provides many possibilities for determining how gender identity is expressed. In one study of teenage chatrooms, Herring (2004) found that word choice and some speech acts appeared to be determined more by the topic of conversation than by participants' gender. However, significant differences were found for the use of other speech acts and overall message tone; and physical stance, dress, and social distance in profile images, functioning as broader, more stable signals of gender identity. Genre also appears to have an influence: Huffaker and Calvert (2005) found few gender differences in lexical choice in teen blogs but were studying only online diaries. Similarly, Koch, Mueller, Kruse, and Zumbach (2005) found few gender differences in their experimental study of gender construction in chat groups, where all the undergraduate subjects were discussing the same topic. It appears that stylistic variables may be more gendered than actual textual acts. Guiller & Durndell, (2007), and Thelwall, Wilkinson, and Uppal (2010) found that males were more likely to use authoritative language and to respond negatively in interactions, while females were more likely to agree explicitly, support others, use more positive tones and make more personal and emotional contributions.

Cultural Differences

Before 2000, most users of online chats were young, male Americans, and although American users now only make up only one-third of the online population, the percentage of English-language Web pages remains disproportionately high (Lavoie, O'Neill, & Bennett, 2003). Conversely, the gender gap appears to be closing even though men still spend more time online per visit and dominate public discussion forums (Herring, 2003; Pastore, 2001). For example, Herring, Kouper, Scheidt, & Wright (2004) found ordinary bloggers were found to be female nearly as often as male, and young (teens or young adults) as often as adult. However, gender and age of bloggers varied according to blog type, with adult males writing almost all filter blogs, and young females writing the largest proportion of personal journals or diary-type blogs.

There appear to be cultural differences in blogging practices, with more users in Spain than Germany, and young, female Poles out blogging males (by 75%) and older adults (Trammell, Tarkowski, & Hofmokl, 2006). Again, genre was related as the Polish girls blogged more frequently about their emotional reactions to events than any of the other groups. However, the blogger profile still tends to be young adult males residing in the USA, followed by Singapore, the UK, Canada, and Australia, many of whom held technology-related jobs such as Web developer, system administrator, and computer programmer. As these occupations are male-dominated a gender disparity continues to emerge.

Herring (2004) acknowledges the "earlier utopian views of the internet as a gender equalizer" that enjoyed a renaissance as the number of female internet users climbed, while "others pointed to a by-then irrefutable body of evidence of online gender harassment." She acknowledges that we "surrendered to the internet, nervously accepted our dependence on it, as the extent of that dependency sunk in." And, even though internet access was rapidly spreading across the globe, including ostensibly flattening boundaries of race and class, "at the same time, for some, the novelty of CMC had already worn off…and some users who had been enthusiastic participants earlier had subsequently scaled back their use, disenchanted with the flame wars, repetitiousness, incoherence, and banality of online public discourse" (p. 28).

Certain gender patterns have been continuously and persistently reproduced over more than two decades of research. While socially facilitative, that is, tacitly understood, gendered power dimensions underlie patterns of discourse (performance): males – dominant and in control, and females – accommodating and anxious to please males. Online environments evidently make gender more salient, manifesting in terms of assertiveness, expression of emotion, politeness, etc. in other types of engagement, including online academic discussions (Guiller & Durndell, 2007, in Kapidzic & Herring, 2011). The question for educators is how the gender identities are performed for better or worse in different communicative settings, and how these environments may be designed to facilitate social equity (Kapidzic & Herring, 2011).

Apart from English-language blogs, the choice of linguistic code in multilingual computer-mediated groups has also been observed to serve different discourse functions (Georgakopoulou, 2011). "Language variety" includes dialect, and the register of the language used. Register refers to specialized "sub-languages" associated with conventional social roles and contexts, such as academic discourse or teacher talk. In these sites, the default dialect is the standard, educated, written variety of the language (e.g., Oxford English), although regional, social class, or ethnic dialects may sometimes be used (Androutsopoulos & Ziegler, 2004). These registers reflect gendered performances in the same way that lexical and stylistic discourse does.

Discussion

While the digital access divide may be narrowing, to date, the greater presence of women has not substantially affected gendered discourse patterns online. Gender identities are revealed through lexical and stylistic patterns, register, and code, regardless of culture. This points to the persistent, fundamental, sociocultural expectations of gender performance. Ferenczi, Marshall and Bejanyan (2017) investigated differences between 573 men and women in social (anti and pro) uses of Facebook. Participants completed measures of narcissism, relational self-construct, and motives for using Facebook, revealing that men reported more antisocial motives than did women, which was explained by men's greater narcissism. Conversely, women reported stronger prosocial motives for using Facebook, which was explained by their more relational self-construct. Gendered behavior has been illustrated in uses to which social media is put, that is, females of all ages trending to more personal uses, while males dominate filtered blogs and "news" sites. Many communities are concerned with the emergence of internet "trolls" who appear to be overwhelmingly male. In a study of 1215 "trolls," Buckels, Trapnell, and Paulhus (2014) found strong positive associations among online commenting frequency, trolling enjoyment, and troll identity, revealing "similar patterns of relations between trolling and the 'Dark Tetrad' (Međedović & Petrović, 2015) of personality: trolling correlated positively with sadism, psychopathy, and Machiavellianism, using both enjoyment ratings and identity scores" (abstract). Frighteningly, of all the personality measures, sadism showed the most robust associations with trolling and was specific to trolling behavior. This behavior has disproportionately targeted females, ethnicities, and sexual orientation (c.f. Ryall, 2017; Wente, 2017). Of concern to educators, as Internet use increases, is whether we can design interventions to promote more prosocial behavior in users of social media.

The seminal work of Susan Herring and her colleagues has been highlighted in the previous section. Herring first examined conversations among adults using computer-mediated tools, more recently, exploring the blogosphere. While this work is not exclusively gendered, the research has consistently shown that the online space is a gendered space in which gendered discourse styles remain consistent through several decades of work. In terms of online learning, we see that dilemmatic spaces in educational contexts have been developed in the tensions between "societal expectations and the historical, cultural, institutional…political and economic prerequisites and the ongoing social, relational and communicative processes" that occur in both structured and unstructured discourses (Fransson, 2016, p. 194). These tensions are very publicly played out in the twelve (or so) years that individuals attend school. In the next section, I share both foundational and more current research about gendered practices related to learning with technology and in the STEM subjects that both reflect and lead to structural social issues of marginalization.

Gender and Pedagogical Practices: Schools and Curriculum

Three decades of research on instructional methods, learning styles, and interests have found that females tend to prefer pedagogies and curriculum design and content that connect in meaningful ways with learners' prior experiences and the world in which they live (c.f. Belenky et al., 1986; Brunner, 1997; Jacobs & Becker, 1997; McIntosh, 1983; Rosser, 1985, 1989). We have seen that these research outcomes, dominated by Western cultures, have focused on "gendered" characteristics rather than the sociocultural contexts that influence learning. However, more current research (see the discussion on self-efficacy, above) suggests that it is particularly important that teachers and curriculum designers in the STEM disciplines attend to the

experience base of female students, connecting learners through their life experiences (c.f. Markert, 2003). For example, a thoughtful curation of OERs (Open Educational Resources) with which learners can identify through gendered lenses may be more relevant than textbooks (Weber & Custer, 2005).

In Canada, performance gaps between boys and girls in science are relatively low compared to those in other Organisation for Economic Co-operation and Development (OECD) countries; however, the OECD highlights that a gap exists between girls and boys in mathematics: Boys' average scores in mathematics were nine points higher than girls' scores. Is this a result of innate ability or a complex weaving of cognitive abilities and sociocultural influences?

Several studies surveyed for this chapter support that belief that females prefer collaboration over competition (c.f. Caleb, 2000; Chapman, 2000) consistent with contemporary trends in technology education, where the "historic use" of individual projects is shifting toward small, collaborative group work (Weber & Custer, 2005, p. 56) With regard to classroom computer use, it is well documented that females' preference for design, especially when activities focus on socially relevant problem-solving, and males' preference for utilization, especially when the activity involves building with tools, is generally consistent with gender stereotypes (Weber & Custer, 2005). Weber and Custer also found that developing engaging construction-related activities for females remains a significant challenge for curriculum developers, observing that the "construction" activities in this study reflected pedagogical strategies favoring debate, research, and evaluation, strategies that are typically utilized by traditional discipline. They concluded that strategies might have as much influence as content. Welty and Puck (2001), for example, found that females' interest increased if the computer was used as a tool to create something like a multimedia presentation, but not if the focus was on learning how to program computers, and that both females and males ranked "lecture" and "lecture with discussion" as the least preferred methods of instruction. The foregoing has implications for gender-balanced topic selection in technology education. An increased emphasis on design in contemporary technology education courses could provide some balance between this design and make/utilize dichotomy (Weber & Custer, 2005). In the public school years, girls and boys take math and science courses in roughly the same numbers. However, by the time they are to choose majors at university, fewer women than men choose these areas of study. By the time they graduate, men far outnumber women in bachelor's degrees awarded, fewer women than men enter graduate programs in these areas, and participation further declines in the transition to the workplace. Students from historically disadvantaged groups, both female and male, are also less likely to have access to advanced courses in math and science in high school, which negatively affects their ability to enter and successfully complete STEM majors at post-secondary level (c.f. Tyson, Lee, Borman, & Hanson, 2007; Perna et al., 2009).

Hill, Corbett, and St. Rose (2010) found that societal beliefs (and discourse), reflected in decisions at home and in school, affect girls' beliefs about their intelligence and ability to succeed in STEM subjects. For example, there is evidence that girls assess their mathematical abilities lower than do boys with similar mathematical achievements while holding themselves to higher standards of achievement. In other words, girls believe that they have to be exceptional in order to find success in "male" subjects or fields. For example, while no definitive evidence proves that strong spatial abilities are required for achievement in STEM careers (Ceci et al., 2009), many people, including science and engineering professors, view them as important for success in fields like engineering and classes like organic chemistry. Girls rate themselves lower on spatial-visualization ability. However, in one pilot study, Sorby (2009) found that middle school girls who took a spatial-visualization course took more advanced-level math and science courses in high school than did girls who did not take the course and recommends that this training happen by middle school or earlier to make a difference in girls' choices.

One outcome of gendered belief is that fewer girls than boys aspire to STEM careers. Many young men in computer science report having had an immediate and strong engagement with the computer from an early age, intensifying in middle and high school. On the other hand, many women who are interested in computer science and have similar talent do not report a similar experience (Singh, Allen, Scheckler, & Darlington, 2007). As STEM jobs are critical to the global economy, women's participation in these fields, currently at 25% overall, is of concern (Lacey & Wright, 2009). Practically, if the design of products and services such as airbags, buildings, cars, and medical interventions does not take into account the differences between men and women (size, voice timbre, hormones, etc.), the consequences can be dire, for example, deaths of women and children in vehicular accidents caused by airbags designed by and tested on male engineers (Hill et al., 2010).

While the Western classroom has dominated research on gender issues, research in Eastern Europe, Africa, Asia, and the Middle East has examined gender differences in approach to technology for learning. For example, traditional Iranian laws hold education accountable for the support of girls' social and political status, emphasizing gender equality in education, and requiring the Iranian Ministry of education to modify educational materials in order to present a gender-neutral picture of women (Ghajarieh & Salami, 2016). The "equal education opportunities" discourse, initially encouraged by many educational institutes in the UK and the US, supports the notion that education should be for both boys and girls; the support of this discourse depends on social and cultural considerations (p. 258).

Learning Spaces

Dominant design practices that, for decades, have centered on 40-year-old, able-bodied males have ignored the needs of groups typically marginalized by design such as women, the aged, the infirm, and the young. Universal design emerged from the political work done by the accessibility movement activists in the 1960s and 1970s. Universal designers advocate for a more diverse range of abilities when designing built environments, thinking systematically about inclusion (Nieusma, 2004, p. 14). Universal scholars from all design fields, including instructional design, are reflecting on how technologies and other designed artifacts, including curriculum and learning resources, are implicated in larger social problems, such as sexism, lack of user participation and autonomy, and restricted access to built environments.

Rendell, Penner, and Borden (2000, in Lång, 2010) describe the built environment as "a cultural artefact that is embedded in the process through which individuals build and form their identities." Consequently, learning facilities will embody cultural values and imply standards of behavior that are transmitted to designers through authoritative voices of planners, and architects. Designing a gender-neutral learning space is challenged by the domination of male decision makers at design and policy levels, and the need to design spaces that respond to different and gendered needs, including those who feel excluded by binary categories (Blaise, 2005). This suggests that planners should consider social intersections that include gender differences (Becker, 2009).

A UNESCO (2017b) study of learning facilities in different geopolitical regions found that, while schools are intended to be places of learning, growth, and empowerment, they can often be sites of intolerance, discrimination, and violence, in which girls are disproportionately at risk. Parents concerned for their child's safety in this study were anxious about mixed gender classes, and the poor educational outcomes of girls in these situations (Lång, 2010). For the most part, classrooms, including computer labs, have not been designed to be gender-neutral, as designers may not be aware of their assumptions about space. For example, spaces that are flexible, allowing for collaborative work; lighting that accounts for security concerns; learning stations that are designed with smaller physiques in mind; technologies that adapt to multiple users' inputs instead of one (usually a male) operator; spaces with extended hours of support and security; open spaces where activity is always visible; even single-sex groupings (although not accounting for Intersectionalities) contribute to more accessible, safer, and inclusive learning environments.

Discussion

Intersecting factors such as gender, identity (e.g., Indigenous), socioeconomic background, culture, language, and ability can affect equitable learning opportunities (c.f. Lee, Kotsopoulos, & Zambrzycka, 2012). In Canada, the disparity is particularly acute for Indigenous children, who, due to a range of social determinants, experience gaps in academic achievement that emerge in elementary school and intensify at higher grades (Richards & Scott, 2009). Evidence points to a range of factors that affect representation by field of study, occupation, and rank, ranging from personal preferences to discrimination and structural barriers (Actua, 2014; NAS, 2007; Hill et al., 2010).

Educational contexts are social constructions reflecting history, economics, politics, cultural values and expectations, policy, and place. Teaching is an incredibly complex activity and teachers, as actors, perform in these multi-layered spaces as curriculum makers and negotiators between parents, learners, colleagues, administrators, and society. Global expectations of schools as safe, effective, and efficient sites of learning have increased, certainly in view of the financial, political, and social investments made in learning technologies. Fransson (2016) speaks about teachers as "manoeuverers" in a context in which "digital technologies construct new dimensions of everyday practice," pressuring them to design with and for these technological environments, even though "this may be at odds with their own knowledge, beliefs, emotion and doubts about their potential" (p. 194). Research about teacher education and classroom teaching has shown that gender is an identity construction that is reflected in an individual's approach to technology and to their beliefs and expectations about gender and technology. For example, parents and teachers alike have expected less of girls in technology environments; in turn, girls expect less of themselves or of their potential for success.

While teachers can do little to intervene in the early childhood years, they can acknowledge the sociocultural forces that have shaped children before they come to school and evaluate their pedagogical spaces, approaches, activities, and curriculum for bias. For example, bias in representation can be detected, and replaced, in learning resources, perhaps with a careful and critical curation of OERs. There has been some success in BYOD interventions, although not all children will easily have access to mobile devices, certainly of the same quality. Learning activities that reflect prior experiences, involve creativity, include narrative, and utilize technologies as tools to solve problems rather than as a focus of interest in themselves has been shown to underlie inclusive classrooms. Critical theoretical models such as "Multiliteracies" above, where learners co-create curriculum out of their own cultural understandings is one evidence-based approach.

We have seen that structural bias influences self-efficacy and attitudes toward STEM subjects. Research has consistently demonstrated that there are no biological barriers to females succeeding in STEM subjects. Self-efficacy can be influenced, though, in a number of ways. Fundamentally, identification of "stumbling blocks" to a successful learning experience, a planned intervention (design), and sufficient attempts to practice with a metacognitive emphasis may begin to shift personal doubts. For example, the work of Sorby (2009) with females who describe themselves as being visually spatially challenged demonstrates that skills can be taught, narrowing or eliminating performance gaps.

Globally, teachers obviously need to be alert to cultural expectations that influence the self-efficacy and performance of girls and women. In many areas of the world, women are already disadvantaged by religion, cultural assumptions, socioeconomic status, and other factors. Western research about same-sex groupings has had mixed results (c.f. Arms, 2010), although there is evidence that same-sex classes remove some performance pressure for girls.

Next, if structural "discrimination" in the K-12 sector has not discouraged them, we will see that females actually outnumber male students in the post-secondary sector, at least in the Western world. What happens to them when they enter programs that are technology-heavy at college, university, and professional education?

Gender and the Post-secondary Learning Environment: Disciplinary Cultures

Statistics Canada reports that, as of 2014, women made up just over one quarter (25.4%) of enrolment in mathematics, computer and information sciences and less than one-fifth (19%) of enrolment in engineering and architecture (MacLean, 2017). In fact, women's representation in computer science is actually declining. While more Indigenous women than men held a university degree in 2011 (13.2% to 7.6%), they make up a proportionately lower portion of STEM-related degrees. The Canadian Council of Academies (CCA) points out that Canada is missing out on an important supply of skilled talent. In a report tabled in 2015, the CCA concluded that increasing the STEM participation of underrepresented populations, including women and Aboriginal peoples, was an important strategy for diversifying the economy. Interestingly, at the higher levels of education, a large proportion of STEM graduates were immigrants (39%); however, women and immigrants tended to have lower incomes and poorer economic outcomes than men and Canadian-born workers overall (Drummond & Fong, 2010). Disparities in Canada are mirrored in the USA where Asian women earn far more STEM degrees (12%) than do African American and Hispanic women (5%), and more Asian women earn master's degrees in STEM (12%) than in other fields (4.5%) (Hewlett et al., 2008).

Many of the men in this, and other surveys, report increasing interest in computer science as they progress through school. Females report more moderate interest in computer science, especially early on, that builds only gradually. Singh and her colleagues (2007) caution that distinguishing between an interest in computer science and an interest in computers and technology is important: Women and men are interested in and equally likely to use computers and technology for educational and communication purposes, but the gender gap in the study of computer science remains. Margolis and Fisher (2002) found that among women and men who had similar grades, women in computer-related majors were less confident than their male peers about their ability to succeed in their major. The group of female computer science majors in the study who were "brimming with confidence and excitement about their major in the earliest interviews were no longer 'buzzing' by the second and third semester" (92), expressing dissatisfaction with the culture of the discipline, and leading the researchers to argue that the decline in women's confidence is a problem of student experience in the institutional culture. Computer science, with its emphasis on basic skills as opposed to problem-solving (Goode, Estrella, & Margolis, 2005), and the fact that complex and more interesting projects are often reserved for advanced courses that come too late for most women (Linn, 2005) may also speak to women's higher dropout rate. Jahren's (2016) research supports this finding, reporting that while 23% of freshmen women in the study of 191 female fellowship recipients reported never experiencing isolation and intimidation as barriers, 12% indicated that they had been sexually harassed as a student or early professional.

As in the public school years, curriculum can signal who belongs in a major. Computer science programs that initially emphasize technical aspects of programming before considering the broader multidisciplinary applications can be a deterrent to students of both sexes, but especially to women, who are more likely to report interest in the use of computing to address larger social issues. Certain STEM subdisciplines with a clearer social purpose, such as biomedical engineering and environmental engineering, have succeeded in attracting higher percentages of women than have other subdisciplines like mechanical or electrical engineering (Gibbons, 2009). Sorby and Baartmans (2000) speculated that the belief that perceived inability in tasks requiring spatial skills, which is emphasized in early engineering education, may discourage women from choosing engineering as a major. Whether or not well-developed spatial skills are necessary for success in science and engineering, they found that spatial skills were improved fairly easily with training, by designing and implementing a successful course to improve the spatial-visualization skills of first-year engineering students who had poorly developed spatial skills. More than three-quarters of female engineering students who took the course remained in the school of engineering, compared with about one-half of the female students who did not take the course. Poor or underdeveloped spatial skills may deter girls from pursuing math or science courses or careers, but these skills can be improved fairly easily.

In terms of pedagogy, some work has been done on cognitive style and computing, with Turkle and Papert recommending "bricolage" as an approach to programming that may be more appropriate to females (1992). Blackwell (2006) explored social context and programming, noting that with differing degrees of self-efficacy, bricolage seems likely to become a feature of end-user programming in the home, for example, but might be framed in a way that is predominantly masculine, that is, the male activity of "tinkering." Finally, while the "single-sex" approach to teaching coding has had mixed success, Werner and her colleagues have found that both female and male pairs of university students, but especially women, were more likely to complete their computer course and major in computer science than mixed-sex pairs or students working solo (Denner, Werner, Bean, & Campe, 2005; Werner, Hanks, & McDowell, 2004). Margolis and Fisher (2002) insist that the goal of curriculum reform should not be to lure "women into computer science but rather to change computer science" (p. 6).

Departmental culture includes the expectations, assumptions, and values that guide the actions of professors, staff, and students; the culture is often implicit. Decisions about how to design and teach classes, assess learning, advise students, and organize activities reflect the norms, expectations and interests of the subset of males who take an early interest in computing and pursue it with passion during adolescence and into college. Margolis and Fisher (2002) illustrate how this pattern of behavior is influenced by a Western culture that associates success in computing with boys and men, excluding girls and women. Within the computing science environment, this male model of "doing" computer science (doing gender?) becomes the measure of success, alienating women who have had a different experience.

These findings are supported by Kugler (200, in Role, 2017), who studied computer science majors at Carnegie Mellon University, showed that while women and men are equally likely to change out of college majors in response to poor grades, the exceptions to that rule are STEM programs, in which women are more responsive than men to the negative feedback of low grades. The authors suggest that STEM disciplines are branded as "too-male"; female students that see their numerical minority status are more likely to perceive low grades as confirmation of their inherent unfitness for a STEM discipline.

When considering the underrepresentation of women in science and technology disciplines and careers, another factor may be that they may find better opportunities elsewhere. Several researchers found that more women than men tended to show aptitude in both math and language skills, and yet, the rate of women choosing STEM careers remained low, perhaps because "people tend to play to their strengths." A longitudinal (1992–2007) study of 1500 college-bound students of above-average intelligence, from the University of Pittsburgh (Wang, Eccles, & Kenny, 2013), concluded that women have broader intellectual talents, which provide them with more occupational options. Among those who had highest scores on both the verbal and the math sections of the SAT, for example, nearly two-thirds were female, while only 37% were male. However, among those who excelled in one area but not the other, 70% of those with high math and lower verbal scores were male, while 30% were female, and vice versa. Of those who scored best across the board, 34% choose a STEM career, but 49% of those who did better in math than in language skills chose a STEM career, showing that a breakdown between verbal and math skills remained a strong predictor of career choice. The gender difference among those scoring higher in math than in language, meant fewer capable women wound up in science and mathematical fields. This seems true even when controlling for other factors such as the socioeconomic status of the participants' parents, their own values when it came to balancing work and family, and their personal perceptions about their skills and interests. Cultural stereotypes may be indirectly pushing women away from scientific fields. Addressing the gender gap in STEM careers may not be so much a pipeline problem or one of intellectual ability but in making these fields more welcoming, accessible, and financially attractive.

In fact, data from nearly 300,000 students in 40 countries who took an international test showed that where women are treated more equally, no gender gap exists in math and science scores, and in a few countries, women even do better (Szalavitz, 2013). In countries such as those in northern Europe, not only are women seen as equally capable of math performance, but both genders have government-required paid family leave available to them, as well as free or cheap access to high-quality day care, making the pursuit of demanding careers in science and technology easier and female role models who do it more visible. However, in countries where those opportunities are rarer, where "using words to win is seen as a more appropriate career for a woman and where women's confidence in their math skills is consistently undermined, then women may find the support and options in non-STEM fields more appealing" (Szalavitz, 2013). Wang et al. (2013) believe that their study provides evidence that females with high math ability also have high verbal ability and thus can consider a wider range of occupations than their male peers, instead of having lower abilities in the first place (Athena factor).

There are cases in which institutions are doing a better job of recruiting and retaining female STEM majors. For example, Whitten, Dorato, Duncombe, Allen, Blaha, Butler, Shaw, Taylor, & Williams (2007) were especially impressed with the model of historically black colleges and universities (HBCUs) for creating electives and building supportive departmental cultures in which a disproportionate number of African American female physicists, and more than one-half of all African American physics degree holders, female and male at all levels, graduate (Whitten et al., 2007). For example, HBCUs did one crucial thing by using electives and other activities providing a path toward a degree for students who did not come to college fully prepared to be physics majors.

Discussion

As this section shows, the underrepresentation of women and girls in STEM education can be attributed, in large part, to the persistence of gender stereotypes that lead to "chilly climates" at school and work. A 2017 UNESCO report concluded that "girls' disadvantage is not based on cognitive ability, but in the socialisation and learning processes within which girls are raised and which shape their identity, beliefs, behaviors and choices" (p. 72), from childhood through tertiary education. The report made a number of suggestions to alleviate this problem, including the following:

- Increasing the representation of women in STEM in the media.
- Making STEM curricula gender-responsive.
- Ensuring girls have female role models in STEM fields and.
- Increasing mentorship opportunities for girls and women in STEM.

Finally, the notion of gender (and equality) has implications for adult and distance learning, in which values like empowerment, emancipation, personal growth, and agency meet the understanding of gendered social practices and include the possibility of individual or collective social action. Heiskanen (2006) proposes "adult education as agency might be a site for understanding, and acting on, structural relations of work and learning that are transactional and always changing" (p. 532) particularly in a "post-truth" society.

Referencing the discussion of the experience of post-secondary education curriculum, structures, and cultures, the final section of this review examines STEM workplaces (although all workplaces use technology in some way). It is reasonable to include this overview of more recent research because arguably the gendered experiences at home, in society, and in school lead resolve into career decisions and worklife. The questions here relate to workplace culture, career progression, and the gender wage gap.

If the path from elementary school to a STEM career is a "pipeline," we would expect that as the number of girls who study STEM subjects in elementary, middle, and secondary school increases, the number of women who emerge from the pipeline into scientific and technical careers will also increase; gender disparities in representation will disappear. However, the next section presents a less positive outcome than we might have expected.

Gender in STEM Workplaces: Intersections with Race and Culture

In the spring of 2006, the Hidden Brain Drain, a 43-company global task force, launched a research project targeting women with degrees in science, technology, engineering and mathematics (STEM) who had embarked on careers in the private sector. The Athena Project, as it was dubbed, conducted four major surveys and 28 focus groups in Boston, Chicago, Geneva, Hong Kong, London, Moscow, New Jersey, New York, Palo Alto, Pittsburgh, Seattle, Shanghai, and Sydney over an 18-month period. The data showed that that 41% of highly qualified scientists, engineers, and technologists on the lower rungs of corporate career ladders were female. Despite the challenges they face at school and in our culture, a significant number of girls begin careers in science. Their dedication is impressive: Two-thirds of female scientists choose their fields to contribute to the well-being of society. But something happens between the early years and the mid-career point: 52% of highly qualified females working for STEM companies quit their jobs, driven out by hostile work environments, including sexual harassment, and extreme job pressures. The Athena Project researchers called these factors the "antigens" – hostile macho culture, individuality, isolation, mysterious career paths, and the "diving catch" culture that rewarded risk-taking.

In most STEM fields, the drop-off is pronounced. For example, women earned 12% of the doctorates in engineering in 1996, but were only 7% of the tenured faculty in engineering in US colleges and universities in 2006 (Hewlett et al., 2008). Even in fields like life sciences, where women now receive about one-half of doctorates awarded, women made up less than one-quarter of tenured faculty and only 34% of tenure-track faculty in 2006 (National Science Foundation, 2008, 2009). The numbers for women of color, Canadian Indigenous and Native American women, and immigrants are more dire. For example, in 2011, female immigrants were the majority of women aged 25–34 years with degrees in mathematics and computer science (65%), and engineering (54%), whereas Canadian-born women represented 70% of all female science and technology degree holders. The data available for Indigenous women in STEM fields indicate similar trends to those for non-Indigenous female STEM degree holders in Canada; in 2011, both Indigenous and non-Indigenous women with STEM degrees were more likely to hold degrees in the science and technology fields. However, only 27% of STEM professionals are women.

Professional Workplaces

Currently, women make up only 27% of the workforce in Canadian.

communications and technology industries, leaving these industries at an alarming rate. In the USA, Hewlitt and others (2008) found that over time, over half of highly qualified women working in science, engineering, and technology companies quit their jobs. In 2013, just 26% of computing jobs in the USA were held by women, down from 35% in 1990, according to a study by the American Association of University Women (Hill et al., 2010). Engineers are the second largest STEM occupational group, but only about one out of every seven engineers is female. In physical and life sciences jobs, however, women made up about 40% of the workforce in 2009, up from 36% in 2000. Another area that has shown growth is STEM management, with women in management positions increasing to 25% overall.

The so-called pipeline problem does not entirely account for these low numbers of participation. Among STEM majors in college, about 57% of female STEM majors study physical and life sciences, while about 31% of men choose these fields. The share of women choosing math majors is also higher than men: 10% versus 6%. However, two and a half times the number of men choose engineering degrees. About equal numbers of male and female STEM majors enter computer science, but men in the workforce with STEM degrees outnumber women across all four fields of study. In short, women with a STEM degree are less likely than their male counterparts to work in a STEM occupation; they are more likely to work in education or health care. There are many possible factors contributing to the discrepancy of women and men in STEM jobs, including a lack of female role models and less family-friendly flexibility in the STEM fields (Beede et al., 2011).

Gender stereotypes contribute to this situation. A 2005 Gallup poll of 1008 adults, aged 18 and older, found that 21% of Americans believed men were better than women in terms of their math and science abilities (though 68% believed men and women were about the same). The higher the education level of the respondent, the lower the belief that men were better, but of the 21% of respondents who believe men have an advantage say it is due to "differences between boys and girls that are present at birth" as say the perceived advantage is due to "differences in the way society and the educational system treat boys and girls" (Jones, 2005). There are gender differences in the participation of men and women in some STEM fields among students, and these differences do contribute to the underrepresentation of women in skilled technical positions as well as in leadership positions: One study places the gender gap at 80% (men) to 20%, whereas about 29% of executive positions in industry overall are held by women (Jones, 2005). Recent commentary in *Inside Higher Education* (Jaschik, 2018) relates unconscious bias in hiring practices of companies that contributed to the gender gap from the beginning of one's career.

Meta-analytic evidence on gender differences in leadership aspirations showed that differences are decreasing over time, suggesting that the gap is more due to society than to biology, although cultural differences do exist (c.f. Gneezy, Leonard, & List, 2009; Li, 2002). In his unfortunate memo to Google staff in 2017, describing Google's culture as an "ideological echo chamber", James Damore cited one study that did find gender differences in personality across cultures, but the researchers described the differences as relatively small to moderate and concluded that "human development—long and healthy life, access to education, and economic wealth—is a primary correlate of the gap between men and women in their personality traits. (Schmitt, Realo, Voracek, & Allik, 2008, p. 180)." At Google, women make up 30% of the company's overall workforce, but hold only 17% of the company's tech jobs. At Facebook, 15% of technical roles are staffed by women. At Twitter, it is 10%. For non-technical jobs at Twitter (e.g., marketing, HR, and sales), the gender split is 50–50, while only 10% of leadership roles are held by women. (Hill et al., 2010).

The underrepresentation of women in STEM majors and jobs may be attributable to a variety of factors, including different choices men and women typically make in response to incentives in STEM education and STEM employment. For example, STEM career paths may be less accommodating to people cycling in and out of the work-force to raise a family – or it may be because there are relatively few female STEM role models. First, let us acknowledge that gender has proved to be a complicated issue for both research and practice. Arguing that action research has the potential of making a contribution to understanding gender issues, Heiskanen (2006) emphasizes that "(change) projects need a concept of gender which includes the relevant aspects of social structure and social process" (p. 519). In the action research, she proposes there is often a tension between organizations who may understand gender as a biological concept, resulting in efforts to remove barriers to equal opportunity. By contrast, Heiskanen (2006) suggests that understanding gender as an activity might "overcome the stable and essentialistic sex/gender dichotomy" (p. 525), including social processes into a "gendered role" (e.g., processes involved in socialization), and taking into account cultural definitions.

Drejhammar (2002) tackles the belief that organizations are, for the most part, gender neutral, although organizations such as schools and workplaces are based on a male norm, "prevent(ing) people from seeing how power and gender are related to each other and what consequences this relationship has for women's working conditions" (Drejhammar, 2002, in Heiskanen, 2006, p. 526). We have seen this in the stubborn gender wage gap, and access to career progression encountered by women in many engineering and IT-related careers (e.g., Silicon Valley organizations like Uber and Google).

Recruitment and Retention in STEM Jobs

While engineering graduates tend to earn more than in other STEM fields, women with a degree or certificate in mathematics and computer sciences may earn almost as much as women engineers. While differences in earnings among fields of STEM education have been relatively stable over time, they do vary by education level and gender. Graduates in engineering, mathematics, and computer sciences have generally enjoyed higher earnings than non-STEM graduates. However, men are more likely than women to graduate from a STEM field. At each level of education, marked differences exist between the proportion of women and men graduates in STEM. Engineering programs are the most popular choice among men and science programs among women. The ratio of women to men graduates is the most balanced in science programs and at the doctoral level overall (p. 104).

Studies of STEM graduates find that women in these fields have higher attrition rates than do both their male peers and women in other occupations, especially at mid-career (c.f. Hewlett and others, 2008). High-tech companies in particular lost 41% of their female employees, compared with only 17% of their male employees. In engineering, women have higher attrition rates than their male peers have, despite similar levels of stated satisfaction and education. The Society of Women Engineers (c.f. Powell, Bagilhole & Daintey, 2009) conducted a retention study of more than 6000 individuals who earned an engineering degree between 1985 and 2003. One-quarter of female engineers surveyed were either not employed at all or not employed in engineering or a related field, while only one-tenth of men surveyed had left the engineering field. Three themes emerge from the literature. First, the notion that men are mathematically superior and innately better suited to STEM fields than women are remains a common belief, with a large number of articles addressing cognitive gender differences as an explanation for the small numbers of women in STEM. A second theme revolves around girls' lack of interest in STEM. A third theme involves the STEM workplace, with issues ranging from work–life balance to bias. An example of how bias and cultural expectations intersect was provided by Heilman and Okimoto (2007), who found that successful women in masculine occupations were less likely to be disliked if they were seen as possessing communal traits such as being understanding, caring, and concerned about others. These authors showed that the negativity directed at successful women in male occupations lessened when the women were viewed as "communal."

McKinsey and Company released a report "Why Diversity Matters" (2015) released new research that shows that US women working in STEM fields are 45%

more likely than their male peers to leave the industry within a year. Over 80% of these women report “loving” what they do. In Brazil, China, and India, the numbers are close to 90%. These women state that they were interested in leadership positions within their fields, but feel marginalized, stalled, stymied by bias and a double standard, and prevented from contributing to their full potential. Similarly, in an online poll of ISACA female members worldwide (2016), 33% explained that the underrepresentation of women in STEM fields was due to information technology role models and leaders being predominantly male (33%). Other explanations were the perception that information technology is a male-dominated field (22%), and the observation that educational institutions do not encourage girls to pursue technology careers (14%). Respondents shared experiences of being overlooked in meetings, having ideas dismissed only to be usurped by male colleagues later, receiving work below their skill and experience levels, and inexplicably being passed over for promotions. Only 22% of the women believed their employers were very committed to hiring and advancing women in technology roles. Even in workplaces with flexible work arrangements, the “flexibility stigma” was observed when women who were encouraged to take maternity leaves were “punished” for deciding to do so. If, within 2 years, 1.2 million jobs in the USA alone require IT skills, at the current rates of recruitment and retention, women will fill only 3% of them (HillsNotes, 2017).

Academic Workplaces

A study on attrition among STEM faculty showed that female and male faculty leave at similar rates; however, women are more likely than men to consider changing jobs within academia. Xue (2008) found that women’s higher turnover was mainly due to dissatisfaction with departmental culture, advancement opportunities, faculty leadership, and research support. Lower satisfaction leads to higher turnover and a loss of talent in science and engineering. The climate of science and engineering departments is closely related to satisfaction of female faculty; providing selective mentoring and work–life policies can enhance the retention of female STEM faculty (Trower, 2008). The climate in STEM departments may be discouraging women with families: Mason et al. (2009) found that the women were 35% less likely to enter a tenure-track position after receiving a doctorate. Former Canadian federal industry minister Tony Clement commissioned a report by the Canadian Council of Academies, that found female academics at all levels earned less than men, and that many promotion and tenure processes lacked exit and re-entry procedures that allow women who take time off to raise children to be considered.

Research has consistently pointed to bias in peer review and hiring. For example, Wenneras and Wold (1997) found that a female postdoctoral applicant had to be significantly more productive than a male applicant to receive the same peer-review score. The female candidate had to publish at least three more papers in a prestigious science journal or an additional 20 papers in lesser known specialty journals to be judged as productive as a male applicant. Similarly, Trix and Psenka (2003) found systematic differences in letters of recommendation for academic positions:

selection committees, the majority of whom were male, relied on accepted gender schema in which, for example, women are not expected to have significant accomplishments. For example, letters written for women were more likely to refer to their compassion, teaching, and service as opposed to their achievements, research, and ability, which are the characteristics highlighted for male applicants, “unknowingly us(ing) selective categorization and perception, also known as stereotyping, in choosing what features to include in their profiles of the female applicants” (p. 215). Studies have shown that employers, and academic peers, do discriminate against women and minorities in hiring, and also in promotion rates, performance evaluations, getting credit for good work, and project assignments. In one study (Moss-Racusin, Dovidio, Brescoll, Graham and Handelsman, 2012), professors rated the identical applications of fictional male or female students. When a male name was used, faculty members rated them as significantly more competent and hirable than the female applicant, and they offered the male applicant a higher starting salary and more career mentoring. The reason for this was that women were perceived as less competent by the faculty members; faculty who had greater bias against women rated female students worse. Intersections with ethnicity paint a bleaker picture: African American women make up less than 1% of faculty in engineering. Even in the life sciences, women of color held about 0.3% of faculty positions (c.f. Frehill, Di Fabio & Hill, 2008).

In October 2014, the Canada Research Chair program published new guidelines for reference letters that provided tips on how to ensure unconscious biases do not undermine female candidates. Referees are encouraged to keep feedback specific to the position and avoid adjectives that characterize women as maternal or agreeable.

Recently, a pan-Canadian expert panel of senior academics analyzed data from Statistics Canada, and other sources (e.g., National Household Survey), concluding

> the reasons to support diversity in Canada’s science departments are many, but perhaps the most practical is simply one of global competitiveness. It is no secret that math and science skills are becoming more important to a thriving economy, and while countries like India and China are churning out ever more science and engineering grads, the numbers in Canada are stagnating. We need all hands-on deck, and that begins at our universities. Council of Canadian Academies, 2015

Sadly, in one study of 20 Canadian research universities, almost all computing science and mathematics departments had women comprising fewer than a quarter of regular faculty. The University of McGill’s mathematics department had only two women among 40 professors, while Laval University’s had only two out of 24. The University of Alberta had fewer than 10% women in any of its STEM departments. Only two universities – the University of Victoria and the University of Ottawa – exceeded the 25% threshold (Kuzmin, Motskin and Gallinger, 2015). The authors point out that in many Canadian universities, a math, computing science, or engineering student “would be lucky to encounter even a single woman professor at the front of the class in any given year — perhaps even over an entire academic career” (nd).

Research Awards

The women who do tough it out are consistently passed over for recognition, and a number of scientists are raising concerns about the lack of female winners of top awards and what it says about women in science in Canada. For example, the National Science and Engineering Research Council (NSERC)'s Hertzberg medal, which is given to Canada's top scientist or engineer each year "for sustained excellence and overall influence of research work" and comes with a $1-million purse, has never been awarded to a woman.

Dr. Kirsty Duncan, Canada's Minister of Science, made headlines in 2016 when she expressed frustration over the fact that female scientists occupy only 30% of the 1612 positions in the Canada Research Chairs Program (CRCP), which is funded by the (federal) Tri-Research-Councils. The statistics for the CRC program are actually (marginally) higher than those for women in STEM fields in general. In 1987, only 20% were female, whereas in 2016, that number had increased to 22%.

At Canadian universities, only 12% of full professors in STEM are female; women are much more likely to be working as contract faculty or as assistant professors. Only 18% of members of the Canadian Science and Engineering Hall of Fame; just 22 out of 186 prizes worth more than $200,000 were given to women by the Natural Sciences and Engineering Research Council (NSERC) between 2004 and 2014; and only 11% of those named to the Royal Society of Canada's Academy of Sciences in the past 4 years were female (Kingston, 2017). Of 22 Canada Excellence Research Chairs, 21 are men and one is a woman. In 2010, the Canadian government named 19 men to the highest tier, and no woman, to the Canada Excellence Research Chairs, which come with a $10-million prize. In the 24 years since the Canadian Science and Engineering Hall of Fame was created, 11 out of its 60 inductees have been women, sparking criticism that because the majority of nominators are male, unconscious bias plays a part in that low number. While the data are from Canadian surveys, they reflect the situation across the Western world.

How can we address this bias in nomination processes? Kuzmin, Motskin, and Gallager (2015) suggest that incentivizing change with resources may result in better outcomes. For example, under the Athena SWAN Charter in the UK., universities are given ratings of bronze, silver, or gold based on their efforts to promote gender equality and racial diversity. In 2011, the UK's chief medical officer announced that the National Institute for Health Research would reserve major funding for schools with a silver or gold rank; the program was so successful in the sciences that it was extended to arts, humanities, business, and law faculties. Ironically, they recount, "even when national governments support systemic change, bias is nearly impossible to eradicate. Maintaining an Athena SWAN award requires a significant amount of paperwork. In 80% of cases, that burden fell on female scientists, and in 49% of cases, they described it as excessive" (np).

Discussion

Women enter STEM disciplines at the same rate as men, but experience a much higher attrition rate. Consistent with research on the "chilly climate" (c.f. Rosser, 1989; Sandler, Silverberg & Hall, 1996), the reasons for the loss of women in these jobs, as well as the low rate of women in leadership positions, are related to workplace culture. Culture embodies social values and assumptions, deleterious to females from childhood through professional training. The issues are acknowledged and policy development reflects, at least, the economic concern that half of a nation's available workforce is underrepresented in key economic drivers such as IT. The so-called "pipeline" problem is less one of recruitment than of retention.

Trower's research (2008) focused on female faculty's satisfaction with the climate in academic workplaces. She identified ten attributes for a supportive environment:

1. Fairness of evaluation by immediate supervisor
2. Interest senior faculty take in professional development
3. Opportunities to collaborate with senior colleagues
4. Quality of professional interaction with senior colleagues
5. Quality of personal interaction with senior colleagues
6. Quality of professional interaction with junior colleagues
7. Quality of personal interaction with junior colleagues
8. "Fit" (i.e., sense of belonging) in the department
9. Intellectual vitality of the senior colleagues in the department
10. Fairness of junior faculty treatment within the department

In essence, female STEM faculty were less satisfied than their male peers were with all 10 factors and significantly less satisfied with three, that is, sense of fit, opportunities to collaborate with senior colleagues, and the perception of fair treatment of junior faculty in one's department; sense of fit was seen as most important in terms of retention and success. The findings from similar surveys in other STEM workplaces indicate that several of these factors can be addressed through initiatives such as awareness training (for unconscious bias), mentoring, and coaching, examination of criteria for advancement, low or zero tolerance for harassment, policies to encourage community engagement, and flexible working conditions, among others. Society benefits from these efforts, as with a more diverse workforce, scientific and technological products, services, and solutions are likely to be better designed and more likely to represent a wider community of users and learners.

Emerging Challenges and Research Directions Beyond 2018

Jo Sanders (2007, p. 23) summarized questions germane to scholars interested in gender and technology research, and impacts on practice such as curriculum development, learning design, pedagogical models, learning spaces, global issues of inclusion, sociocultural influences on school program and career choices, workplace support, and other issues raised in this chapter, several of which I have updated and shared below (dubbed "dissertation topics"):

- We know that parental influence on daughters' technology interests and behavior varies by SES and educational level, but how does it vary by racial/ethnic group?
- There is a great deal of research on attitudes and on behavior, but what is the causative direction? Does it vary by student characteristics? If so, which characteristics are relevant?
- Does computer game-playing in childhood lead to technology competence and careers as adults? What kinds of games? In what circumstances?
- If game-playing is gendered, what are the implications for design and use in educational settings?
- Is stereotype threat a consistent factor in females' computer technology behavior and performance? How can we intervene successfully?
- What is the relationship, if any, between role models and females' academic achievement and persistence in technology? How does this vary by race/ethnicity, geopolitical location, access, policy environment, and other characteristics?
- What is the relationship, if any, between support groups and females' academic achievement and persistence in technology? Does this vary by race/ethnicity, socioeconomic status, or other characteristics?
- What is the relationship, if any, between collaborative learning and females' academic achievement and persistence in technology? Does this vary by race/ethnicity or other characteristics? Is this inherently gendered?
- What is the relationship, if any, between single-sex learning environments and females' academic achievement and persistence in technology? Why is this model controversial?
- Are there curricular approaches that correlate with persistence in technology?
- What curricular approaches are better for different groups of learners, and which characteristics are relevant in light of females' (and males') multiple learning styles?
- Is gender neutrality a desirable design goal? Is it even possible?
- How should learning facilities be designed to support gender differences?
- What approaches to professional development are most effective with different groups of instructors, and which characteristics are relevant?
- What is it that makes teachers want to help close the computer gender gap? Could that motivation or skill set be more widely shared with their colleagues on a global scale?
- If gender differences in learning are seen to exist and persist, how can we prepare instructors and designers to account for them?
- How can we educate our graduate students in educational technology and learning design to be aware of and include global perspectives?
- What can we learn from different cultural perspectives and research?
- How can we move from short-term research design and intervention to longer term investments? How can we persuade funders to support this research?

- How can we open the conversation about epistemology so that scholars are able to better match their own understandings and values to significant research questions and forms of inquiry?
- How can we refocus research away from the "female deficit model?"
- How can we include the value of "intersectional" research to expand the scope of the questions asked and paths followed?
- Will technological disciplines change if they are approached from different points of view, with different desired outcomes, indeed, with different understandings of the disciplines themselves?

This chapter has tried to reorient our usual habits of scholarship away from well-defined categories and frameworks of educational technology research by focusing on the wider sociocultural impacts of technology on the intersections of gender, race, age, culture, disability, access, socioeconomic status, and politics. Sanders (2007) describes a need to "re-imagine technology, to shift it from what it can do to what it can serve, and in so doing to free ourselves from the conceptual constraints posed by 'business as usual' according to the male model" (p. 24).

At the beginning of this chapter, I provided the briefest of overviews of this research before 2005, proposing that it emphasized the "deficit model" and relied on what Reeves characterizes as "disconnected" thinking. Table 1 summarized this period of scholarship.

Similarly, Table 2 identifies scholars, research questions, outcomes, and recommendations for research and practice from 2005 to 2017, and hopefully points to emerging trends in research and understanding.

Gender and Design Thinking

Bronwen Rees, a designer of user experiences, declares, "as designers our … responsibility is to make the (user) experience as inclusive as possible; when we fail to do that it may be a hurtful reminder to some people of how their journey/identity is not reflected in the world. However, gender sensitive designs offer alternative possibilities for a world respectful of gender diversity" (2017, https://uxplanet.org/when-no-gender-fits-33301c3cab53). Unfortunately, our world continues to be designed with the male user in mind, more often than not, unconsciously. Rees offers the example of Virtual Reality (VR) as an example, where headsets that do not fit smaller female heads, too-large augmented reality glasses whose lenses are too far apart for the average female eye, and the gloves are too big for easy movement. The choice of avatar is another example implicated in the use of pedagogical agents, which default to a white male "norm." Rees offers "identicons," unique geometric patterns generated based on a hash of user's IP addresses, as an alternative. Similarly, and as we saw earlier in research (Navarro, Martı'nez, Yubero, & Larran˜aga, 2014), Rees urges designers to eliminate thoughtless association of colors with gender, which "means resolving the tension between current conventions

Research and recommendations circa 2005–2017

Issue	Findings	**Recommendations**
Culture and gender stereotypes: Bias and representation	Stereotype threat	When threat was removed by telling the students that women and men performed equally well on the test, the women performed significantly better than the men
		Stereotype threat can be alleviated by teaching students about it, reassuring students that tests are fair and exposing students to female role models in math and science
		Encouraging students to think of their math abilities as expandable can lift stereotype threat and have a significant positive effect on students' grades and test scores
		Encourage students to have a more flexible or growth mindset about intelligence
		Teach students and teachers about stereotype threat
Gender and psychosocial factors	Schools, departments, and workplaces can cultivate a culture of respect Females prefer design, especially when activities focus on socially relevant problem-solving, and males prefer utilization, especially when activity involves building with tools Fewer girls than boys aspire to STEM careers Girls believe that they have to be exceptional in order to find success in "male" subjects or fields Structural bias influences self-efficacy and attitudes toward STEM subjects Self-efficacy beliefs are influenced by different sources, including social modeling; with previous performances the main source of influence	Teachers and professors can reduce reliance on stereotypes by making performance standards and expectations clear
		Skills can be taught, narrowing or eliminating performance gap
		Experiential learning activities trump lectures
		Design more collaborative activities
		Identify of "stumbling blocks" to a successful learning experience, plan an intervention (design), and provide sufficient attempts to practice with a metacognitive emphasis

Table 2 (continued)

Issue	Findings	
Gender and generational differences	More females than males use social networking sites, especially ages 12–24 Males make more posts to blogs while females tend to follow conversations Older women (55+) have embraced social media at a greater pace than men in the same age group Culture, e.g., social demographics, influences social media (and other uses of IT), females lag males in all but highly developed countries Males are the biggest users of mobile technologies While adolescent males and females use social media equally, males spend more time gaming	Macro-social variables (such as public policy) influence inclusion of seniors Increase public spaces available for seniors to use ICT Public investments in access, security, etc. encourage wider adoption by seniors User experience designers should be aware that 45+ women drive the greatest proportion of growth for social networking,

From digital access divide to social inclusion: Gender and digital fluency	Stakeholders will gain a better understanding of relevant contexts by supporting the collection, tracking and analysis of sex-disaggregated data on Internet access and use	Make sure gender advocates and experts are involved in the development of broadband, ICT, and other policy – and that they are involved from the outset of this process.
		Integrate gender perspectives in relevant strategies, policies, plans, and budgets.
		Address barriers related to affordability, threats that hamper access and use, digital literacy and confidence, and the availability of relevant content, applications and services
		Supporting stakeholders to collaborate more effectively in addressing digital gender gaps by sharing good practices and lessons learned.
		Use big data to measure women's and girls' Internet use.
		Establish time-bound targets to achieve gender equality in access *and* use, and ensure that sufficient money and resources are allocated to achieve these targets
		Work with government, private sector, and civil society to invest in early intervention digital skills training for women and girls, and that educational opportunities are available at all levels on subjects ranging from basic training to more advanced programming and design
		Focus on public access solutions that will enable women and other populations that might not be able to afford a broadband connection to participate online
		Ensure and communicate efforts to ensure security and privacy of users, with particular focus on groups that are at heightened risk of online abuse, such as women, girls, and LGBT+ persons.

(continued)

Table 2 (continued)

Issue	Findings	Recommendations
Gender online: Social media, age and culture	Gendered discourse patterns have not substantially changed over three decades of study The patterns are observed even in teen chats Gender differentiation by language and style serves a socially facilitative purpose Males dominate news blogs and make more postings, while females write the largest proportion of personal-type blogs Social media use is influenced by culture Women and other marginalized groups are disproportionately targeted by internet trolls	Develop baseline indicators for all strategies, policies and plans related to Internet access and use
		Conduct consumer insights research to better understand the needs, circumstances, and preferences of women and girls, and the factors limiting women's and girls' access to and use of the internet, including for the different women in each market
		Companies should set up, in consultation with their users (including users belonging to marginalized groups), monitoring complaint and redress mechanisms to duly address abusive use of their platforms and services
		As a matter of policy, companies should also strive toward including content that challenges gender stereotypes and provide equitable space for women-curated online content

Gender and pedagogical practices: Schools and curriculum	Girls with a *growth* mindset are more likely than girls with a *fixed* mindset to maintain their confidence and not succumb to stereotypes Spatial skills are not innate but developed and can be taught Carnegie Mellon University is combatting the gender biases that often discourage women from joining the tech world In CMU's 2017 incoming class, 48% of female first-year undergraduates enrolled in School of Computer Science; 43% in College of Engineering	Teach children that intellectual skills can be acquired.
		Encourage children and students to play with construction toys, take things apart, and put them back together again, play games that involve fitting objects into different places, draw, and work with their hands.
		Attend to the experience base of female students, connecting learners through their life experiences.
		Teach girls that intellectual skills, including spatial skills, are acquired.
		Use handheld models when possible (rather than computer models) to help students visualize what they see on paper in front of them.
		Praise children for effort; highlight the struggle.
		Spread the word about girls' and women's achievements in math and science.
		Explore programs like Summer Engineering Experience for Girls (SEE, 2007), run by Engineering Research Accelerator, bringing 27th & eighth grade girls to campus to foster their curiosity in STEM. SEE program aims to reveal influence middle school girls can have on the world by acquiring advanced math and science skills early on. Mentors include undergraduates, *like Mechanical Engineering* (MechE) *and Biomedical Engineering* working alongside faculty
		Help girls recognize their career-relevant skills
		Encourage high school girls to take calculus, physics, chemistry, computer science, and engineering classes when available
		Girls Who Code organization gives internships, fellowships and encourages girls to explore computer science degrees

(continued)

Table 2 (continued)

Issue	Findings	Recommendations
Gender and the postsecondary learning environment: Disciplinary cultures	Women's representation in computer science is actually declining Implicit bias is common and influences girls' and women's likelihood of cultivating an interest in math and science The number of doctoral degrees in STEM disciplines earned by women from underrepresented racial-ethnic backgrounds increased during the past four decades… …but still remains a small proportion of the total. E.g., (2007) African American women earned 2.2% of the doctorates awarded in the biological sciences, <2% awarded in engineering, computer sciences, physical sciences, mathematics and statistics; even smaller for Hispanic American women and smaller again for indigenous women The culture of academic departments has been identified as critical issue for women's success in earning college degrees in STEM fields Teacher education faculty must urge students to scrutinize their practices as it relates to establishing gender responsive pedagogy in SMTs education	Provide a broader overview of the field in introductory courses
		Address peer culture
		Create an environment that supports retention with strategies like same-sex groupings, using "wicked problems" as curriculum, sponsoring departmental social activities, provide a student lounge, actively recruiting students into the major, sponsoring a "women-in-physics" (or computing science, or chemistry, or engineering, etc.) group
		Use a design thinking approach
		Send an inclusive message about who makes a good science or engineering student
		Emphasize real-life applications in early STEM courses
		Broaden the scope of early course work
		Pathways rather than pipelines challenges the notion of a singular, linear route to becoming a (computer scientist, engineer, physicist), which is more likely to reflect a white male experience
		Teach professors about stereotype threat and the benefits of a growth mindset
		Make performance standards and expectations clear in STEM courses
		Raise awareness about bias against women in STEM fields
		Send an inclusive message about who makes a good computer science student

Gender in STEM workplaces: Intersections with race and culture	Women are less satisfied with the academic workplace and more likely to leave it earlier in their careers than their male counterparts Female STEM faculty less satisfied with how well they "fit" in their departments, opportunities to work with senior faculty; institutional support (including funding councils) for having children family while on tenure track Social disapproval, i.e., *double bind*: women seen to be less competent in STEM fields unless they are very successful, BUT Competent women in STEM are seen as less "likeable" Likeability and competence are factors in success in workplace One overarching key factor identified as necessary for improving gender diversity Is ensuring that corporate policy and culture fully align Recruit at universities on an internship basis for roles that clearly are targeting women technologists to apply Successful technology internships will encourage a new level of confidence in ability to succeed *Flexibility stigma*: It is not enough to simply offer flexible options; the options must be exercisable without consequence	Implement mentoring programs and elective work-life policies for all faculty members Ensure mentoring for all faculty Conduct departmental reviews to assess the climate for female faculty Improve departmental culture to promote the integration of female faculty Recruit and retain women by making changes such as gender-blind recruitment and promotion practices, setting targets for women's engagement, and tying mentorship outcomes to performance compensation

and our desires for inclusive design." She concludes with a tenant of universal design, that is, creating inclusive digital environments that embrace inclusivity, understanding, and acceptance is empowering for all users, not just those that are "excluded" by the norm.

Designing for gender equity – in learning, playing, and working – is a "wicked problem." Brown (1992) describes a wicked problem as ill-defined, complex, and usually involving multiple stakeholders and decision makers with competing values. While with decades of research and practice we are learning more about multiple oppressions and their impact on learning, social constructions of gender have proved stubbornly immune to intervention. In this chapter, I have tried to lay out the effect of these constructions on the experiences of girls and women throughout their early learning encounters to their choices of careers that are technology-based, as all careers are trending to be. Comfort and success with technology will be essential in a world with "unaffordable or unavailable health care, billions of people trying to live on just a few dollars a day, energy usage that outpaces the planet's ability to support it, education systems that fail many students…(and) companies whose traditional markets are disrupted by new technologies or demographic shifts" (Brown, 1992, in Blizzard, 2013, p. 30). While formal education is not the only environment in which we can challenge hidden assumptions, unconscious bias, gender stereotyping, cultural beliefs, and social structures that have prevented women from experiencing satisfying, sustainable, and impactful lives, it is an environment amenable to design thinking. Design thinking employs both divergent and convergent thinking to ensure that many possible solutions are explored, and then narrowed down to a preferred solution. Meinel and Leifer (2011) describe a 5-stage process: (re)defining the problem, need-finding, and benchmarking, ideating, building, and testing.

Design thinkers are able to tolerate ambiguity, handle uncertainty, make decisions, collaborate, and think and communicate in the several languages of design, and imagine the world from multiple perspectives (empathy). Their practice is human-centered, iterative, creative, and practical. They bring these characteristics to problem-solving (c.f. Dym, Agogino, Eris, Frey, & Leifer, 2005).

The focus of this last section is designer education for design thinking. Scheer, Noweski and Meinel (2012) describe design thinking as constructivist learning design, "because of its qualities in training certain skills, which are predispositions for a constructive way of learning: motivation for exploration, openness for new ideas, creative thinking and other metacognitive competences" (p. 11). Design thinkers will be more likely to consider the wicked problems underlying the design and delivery of high-quality and equitable learning environments, and to design *for* design thinking in their own work.

Scheer and others (2012) promote constructivist design that is participatory and interdisciplinary. Blizzard (2013) suggests four pedagogical forms that contribute to the development of design thinking: (1) make content and learning objectives relevant to learners' lives, that is, authenticity; (2) provide the opportunity for learners to choose their own topics or projects; (3) include γ group work and activities that encourage learners to not only work together but also learn from each other; and (4). support peer-teaching (p. 36). de Corte (2010) adds that learning should be con-

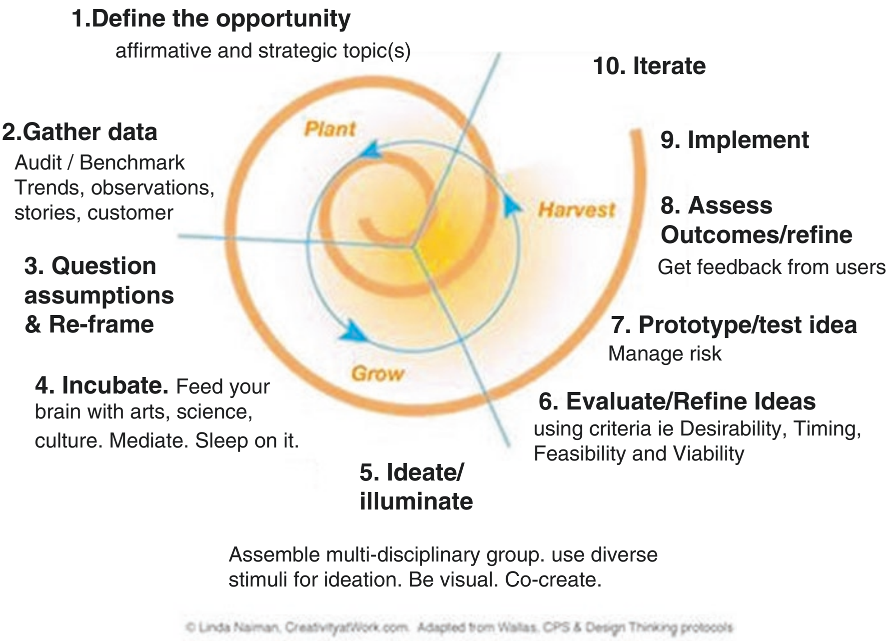

Fig. 2 A framework for creativity and innovation

structed, situated in context, self-regulated, and collaborative. Likewise, David Jonassen's seminal work in problem-based learning (PBL) is foundational for design thinking in its move away from didactic teaching in which learners accept received wisdom, that is, the canon. PBL helps students participate in change, make critical, creative, and reasoned decisions in unfamiliar situations, adopt a more universal or holistic approach, play the "believing game," develop resiliency, and collaborate productively with others.

Design thinking brings Fransson's (2016) notion of dilemmatic space and Mezirow's (2009) theory of transformative learning together with pedagogical models (e.g., PBL, experiential learning) that nurture uncertainty, perspective-taking, and critical thinking. Figure 2, (CreativityWork.com) illustrates the process of design thinking. Compare this process with the assumptions underlying ADDIE.

Applied to design education that acknowledges gender differences, gendered identities, and socially constructed environments (such as schools) that are gendered, design thinking encourages asking critical questions about learners' cultures, relevant societal problems that might form cases, perspectives to include in understanding and seeking solutions to issues at hand, adaptable tools that can be used to design interventions and outcomes, alternative assessment approaches, and opportunities to interrogate one's own assumptions and biases, as well as those of others.

It is important for design educators to be aware of the deep and rich, and often contradictory, literature base about gender and technology. As design is socially constructed, perhaps we can also be agents of disruption of the prevailing design discourses. For example, can we disrupt the notion of design as neutral?

Although it is difficult to imagine that designers can, themselves, fundamentally affect the changes in educational environments, workplaces, and acts of daily living that would contribute to gender equity in these places, we can at the very least be critical of the way we practice and the assumptions that are hidden from view. No checklist of design principles will help with that and reflect the urgency of designing for social inclusion.

In his article for Harvard Business Review, Tim Brown of IDEO offered insight into the "personality profile" of a design thinker. Characteristics to look for include empathy – they imagine the world from multiple perspectives, integrative thinking – they can analyze at a detailed and holistic level to develop novel solutions, optimism – they do not back down from challenging problems, experimentalism – they ask questions and take new approaches to problem-solving, and collaboration – they work with many different disciplines and often have experience in more than just one field (Brown, 2008) Blizzard, p. 11.

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