Willie Pearson, Jr. · Lisa M. Frehill
Connie L. McNeely *Editors*

Advancing Women in Science

An International Perspective

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Foreword

Since the late 1970s, in both the United States and Europe, there has been innovative and important academic work on the interrelations between gender and science, technology (mostly information and communications technology, ICT), and innovation.[1] This work was then extended to other regions where science and technology were less developed (such as Latin America).

Lerman et al. (2003) and Wajcman (2004) place the beginnings of feminist research on science and technology in the 1970s. These authors are among those who made significant contributions to the start and development of this field. In the 1980s, these studies illuminated the important progress, which was enriched and enhanced substantially from the 1990s to today (e.g., Haraway 1985; Plant 1988; Turkle 1995). Gender equality became a central concern for research and science policies in the European Union (EU) beginning in the 1990s. For example, in the EU's Sixth Framework Programme (FP6), gender equality was addressed both in quantitative terms (emphasis on increasing the number of women scientists) and in qualitative terms (the recognition of gender as an analytic category to be included by researchers in this field); since then, it has been sustained by continuous programs supported by the EU.

A turning point in Latin America was the UNESCO (United Nations Educational, Scientific, and Cultural Organization) Regional Forum on Women and Science (Bariloche, Argentina, 1998), which laid the foundation for the World Conference on Science for the XII Century: A New Commitment – UNESCO (Budapest, Hungary, 1999), which, in turn, led to the creation of the UNESCO Regional Chair for Women, Science, and Technology in Latin America, based in FLACSO Argentina.[2] Other important "drivers" in the advancement of this field have been the Ibero-American Conferences on Science, Technology, and Gender, which take place every 2 years; the first was celebrated in Madrid in 1996.

[1] The literature on Gender and Science is too vast to account for it in this foreword. I will refer primarily to three of the most cited sources: Harding (1986, 1991), and Fox Keller (1995).

[2] Facultad Latinoamericana de Ciencias Sociales—Sede Académica Argentina.

In general, in a slow but persistent manner, a corpus of knowledge has been developed by the intertwining of science and technology (S&T) with diverse social science and humanities disciplines in terms of both theory and application (e.g., history, sociology, anthropology, cultural studies, education, philosophy, epistemology, and gender studies or feminist theory). In spite or because of important theoretical and methodological differences, the research in these fields has contributed (both implicitly and explicitly) to problematize what was considered universal, objective, and neutral knowledge and scientific and technological practices and products, revealing their connections with beliefs, values, and gender stereotypes predominant in the socio-historic context in which S&T is produced, disseminated, legitimized, and used.

Research also has shown male dominance in these fields, not only in terms of numbers, or in their presence in decision-making in S&T institutions, but also in the construction of what is conceived and valued as scientific and technological knowledge, demonstrating its androcentric or patriarchal biases concealed by the accepted criteria of rationality, validity, relevance, and excellence. Sara Delamont (1997), for example, points to the bias in science studies "towards exciting, high status men working in elite centres of "big science" excellence," rather than the "routine science" in which most women are involved.

Many studies across disciplines have also consistently provided evidence on a set of issues that affect each other reciprocally: the "invisibilization" or devaluation of women's contributions to the development of S&T throughout history, which has led to some impressive and somewhat "archeological" recovery work through biographies of women researchers and inventors who have been ignored since ancient times to the present, or who simply did not receive the same recognition and acknowledgement as men. Research also has examined both latent and manifest sexism in S&T education, expressed in the curricula and educational materials, student/teacher interactions and peer relations, and the "chilly" climate which undervalues women's capabilities in scientific careers, especially those in which they are a minority, such as engineering and informatics—all factors that tend to discourage girls and young women from choosing S&T as fields of study and professional careers. Virtually all the work in this area reaches the same conclusion, which was expressed in the 1995 United Nations Fourth World Conference on Women Beijing, China:

Science curricula in particular are gender-biased. Science textbooks do not relate to women's and girls' daily experience and fail to give recognition to women scientists. Girls are often deprived of basic education in mathematics and science and technical training, which provide knowledge that they could apply to improve their daily lives and enhance their employment opportunities.

Another line of research deals with the complexity of obstacles that limit the full participation of women in S&T professional work in universities and in the private sector, including those that were evident in the past and therefore more easily challenged, as well as those that were embedded in institutional cultures that have a powerful influence in maintaining gender inequalities and discriminatory practices. Another line of research focused on recovering and analyzing the knowledge created by women's groups in different cultures on issues related to health, agriculture, astronomy, and chemistry, among others, that have been ignored for decades and not validated as scientific.

These lines of research continue to provide new findings, and to stimulate and inform lively debates. The development of different theoretical trends within gender or feminist theory (liberal, marxist, radical, postmodern, cyberfeminist, post-colonial, queer, etc.) is also inspiring new debates, questions, and research problems.

Following Londa Schiebinger (2010), among the research institutions, non-governmental agencies, and governments that have developed gender equality S&T policies over the past several decades, we can identify three categories of strategic approaches:

1. *Fix the numbers of women* focuses on increasing women's participation in S&T. This strategy tends to make women "the problem" (their lack of education, motivation, self-devaluation) and, as a "solution" proposes more education and empowerment. Gender bias in S&T foundations, developments, results, and institutions that produce it is often ignored. One of its consequences is that, "to achieve success, women or girls are often required to assume male values, behaviors, and life rhythms." Note, however, that the inclusion strategy that prevailed for decades has moved from a formal approach to equal opportunities, to the analysis of the roots of marginalization and the systematic invisibility or devaluation of women's contributions to S&T, investigating the diverse effects of a "gender blind" science and the meaning that this segregation has on the production and uses of knowledge.
2. *Fix the institutions* promotes gender equality in careers through structural change in research organizations. In this regard, knowledge and the systematic use of gender-based analysis for planning, mentoring, and assessing policies, practices, and programs are essential, to which should be added the creation of new and more sensitive indicators on gender differences and inequalities. Accordingly, structural change cannot be limited to gender equality in quantitative terms. It requires institutional changes including, for example, norms, structures, criteria for recruitment, assessment and promotion, priorities in research agendas, and assigned funds, as well as less obvious matters such as everyday interpersonal relationships, language, organizational climate, and organization of the work process, among others.
3. *Fix the knowledge* or *gendered innovations* posits that science, technology, and gender representations and values are co-constructed through interaction processes in socio-cultural contexts. This approach is quite recent and promising, and it has been used especially in gender and ICT studies. The goal of this strategy is to "create gender-responsible science and technology, thereby enhancing the lives of both women and men worldwide." Lastly, and with the horizon in sight, it states the need to develop methods and studies to enhance excellence through gender analysis for basic and applied research in science, medicine, and engineering "as a resource to stimulate creativity (…) and by doing so to enhance the lives of both men and women."

The related literature—especially reports from conferences, workshops, and other events where these topics have been discussed—makes clear that many researchers intend for their findings to motivate processes of change and inform policy making. Although the relationships between research on gender in S&T and on policy making in these fields are more complex and slower than we would prefer, there have been important advances towards achieving this fundamental goal.

The chapters and vignettes included in this volume are a part of this journey.

April 2014 Gloria Bonder

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Acknowledgments

This project has a long history that dates back to a 14–15 November 2005 Organization for Economic Cooperation and Development (OECD) Conference on Declining Student Enrolment in Science and Technology held in Amsterdam, The Netherlands. During this meeting, a small group of women and men decided to mobilize and focus global attention on the cross-cutting theme of gender. At the time, however, the group quickly discovered that related cross-cultural research was somewhat limited. Consequently, the group agreed to seek funding to bring together an international cadre of scholars in a workshop format with the goal of producing an edited volume to address the critical issues surrounding the topic. Daryl Chubin, Cheryl B. Leggon, Shirley M. Malcom, Willie Pearson, Jr., and Terry Russell (as principal investigator) developed and submitted a proposal to the United States (US) National Science Foundation (NSF) that was funded (NSF/EHR Grant No. 1048010), with the award going to the Association for Institutional Research (AIR, Russell's affiliation). This project would have been difficult to implement without the strong support of our Program Officers: Myles Boylan and Carol Stoel. The primary role of Program Officer for the project was assumed by Carol Stoel; to her, we owe a great deal of gratitude for her continued encouragement when confronted with many logistical challenges. We also appreciate the support of two other NSF officials. Barbara Olds (former Program Officer, NSF) served on the OECD Conference Organizing Committee and played a major role in inviting the US conference attendees. Wanda E. Ward (former Acting Assistant Director, Division of Education and Human Resources, NSF) participated in the OECD Conference and the resulting two major workshops that were convened for the project. In addition, special thanks are due to former US Ambassador to the OECD, Constance A. Morella, who attended the 2005 conference and supported the project during her tenure.

Shortly after the grant award, Russell retired and the project was transferred to the Commission on Professionals in Science and Technology, which held the first workshop, with Lisa Frehill joining as the new principal investigator. Subsequently, the project was transferred to the US National Academies, which held the final workshop in 2011 and produced the 2012 workshop report, *Blueprint for the Future: Framing the Issues of Women in Science in a Global Context*.

This edited volume is the culmination of the original goal. Throughout the long, arduous journey, Chubin, Leggon, Malcom, Pearson, and Russell remained committed and, along the way, several others joined in to complete the journey and bring the project to fruition. We are especially grateful for the persistence and dedication of Lisa Frehill and Connie McNeely, and also of Alice Abreu, Jann Adams, Sybrina Atwaters, Josephine Beoku-Betts, Lisa Borello, J. McGrath Cohoon, Catherine Didion, Wendy Hansen, Marta Kisilevsky, Robert Lichter, Anne MacLachlan, Mariko Ogawa, Anne Pépin, Cheryl de la Rey, Diane Wilcox, and Kathrin Zippel.

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Contents

Chapter 1
An International Perspective on Advancing Women in Science

Lisa M. Frehill, Connie L. McNeely, and Willie Pearson, Jr.

Many countries have implemented policies to increase the number and quality of scientific researchers as a means to foster innovation and spur economic development. In many cases, policy interventions have sought to increase participation by those who have traditionally been underrepresented in science, with particular reference to women. Today, even in countries with persistently strong patriarchal regimes, the extension of educational opportunities to women has been framed as a means of making better use of the potential pool of science and engineering innovators (Bielli et al. 2004; UNESCO 2007, 2010; CNRS 2004; NRC 2011). Women and, also, in many countries, members of ethnic minority groups traditionally have been limited in access to high-quality education, with concomitant occupational outcomes. Positing the importance of education to development and progress, universal primary education is one of the United Nation's Millennium Development Goals. However, participation in the scientific workforce necessitates education far beyond the primary level—an expensive enterprise, and one in which girls and women have been persistently disadvantaged.

This volume constructs bridges across different perspectives on related issues by weaving together three expanded and critical strands of research on women's

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participation in science to articulate a comprehensive treatment of cross-national similarities, differences, and interactions. The three strands are

- Globalization
- The social organization of science
- Gendered societal relations

First, *globalization* is especially relevant, particularly in reference to the transformation of systems of production. The relative place of an economy within the global world system, the pace of change and historical conditions, and the capacity of individual countries to deploy resources to build a science enterprise have implications for women's participation and status in science, and vice versa. The increasingly global science enterprise shapes national labor markets and opportunities for scientists in general and women scientists in particular as knowledge workers.

Second, social science research on the *social organization of science* is foundational for understanding the conduct of science at the global, regional, and national levels. This point also highlights the importance of policy interventions and governments as supporters of science and the fundamental changes that have been wrought in the locus of scientific work. Moreover, the conduct and movement of science and its further stratification across sectors—academia, government, and industry—speaks to variation in how science is organized cross-nationally even as institutional isomorphism drives similarity.

Third, research on *gendered societal relations* impacts the structural and cultural interactions and dynamics of scientific work itself. Horizontal and vertical dimensions of occupational sex differentiation and segregation impact the career prospects of women in the sciences. Although the representation of women varies within and across scientific fields, it is still the case that, in most fields and in most contexts, women are consistently underrepresented in effective decision-making and leadership positions, even in fields in which they reflect high levels of degree attainment and scientific expertise. Gender bias often still outweighs competency and skill in many venues, especially those in scientific communities in which practice and decision-making are dominated by privileged elites. Despite apparent gains in the numbers of women in some science fields, the larger structure of marginalization persists, as women continue to be systematically barred from authoritative positions with decision-making power.

Taken together, the three research strands—globalization, the social organization of science, and gendered societal relations—as explored in this book, represent key social forces and offer an analytical framework within which to address foundational issues affecting women's participation in science. By interactively engaging the strands, this volume seeks systemic solutions to the challenge of building an inclusive and productive scientific workforce capable of creating the innovation needed for economic growth and prosperity.

The productive relationships and resources of science are organized largely as disciplinary communities. While the boundaries among disciplines may be blurring with the advent of more inter-, multi-, and trans-disciplinary work, disciplines continue to wield substantial power in prescribing behavior and conferring status within scientific communities. For example, scientists, as do other professionals, exercise discipline-based control over entrance into the community, now defined largely via the global university system (Drori et al. 2003; Frank and Gabler 2006).

Along the same lines, disciplines and scientific communities also span national borders. International collaboration across employment sectors—with academia actually lagging the private sector—has become normative for scientists and engineers (e.g., Falkenheim and Kannankutty 2012). Scientists' status and prestige within their fields are increasingly bound up with the ability to build an international, rather than a strictly national, reputation. Also, as has been the case for the past 20 years, graduate students and postdoctoral researchers often cross national boundaries to obtain credentials, with many remaining in the country of training after they have completed studies (National Science Board 2014; Finn 2012; Hamilton et al. 2012). Furthermore, multinational industries locate research and development centers across the globe in search of production advantages and to exploit and tap the diversity of human talent, along with strengthening collaborative ties with universities (Thursby and Thursby 2006).

This volume also includes chapters focused primarily on women's participation in the chemical sciences, mathematics, statistics, and computing, as four such disciplinary sites and communities that maintain independent organizing structures but also involve intersecting material interests. Many important works on women in science have employed a high level of aggregation (e.g., UNESCO 2007; AAUW 2010; IAC 2006; INAS 2013), the result of which is that the experiences of those in the largest general field of science, the life sciences (a field with a high level of women's participation at all educational levels), often dominate the discourse about women's status in science, missing important variations in the educational and occupational realities for women in fields with proportionately fewer women.[1] Such aggregation can obscure specific disciplinary contexts, functional tasks, and the socio-historical conditions that can vary markedly across fields.

Given the powerful force of globalization of labor and capital, attention to disciplines such as the chemical sciences and computer science can shed important light on likely trends that also will occur in other science and engineering fields. Along with these disciplines, the foundational nature and cross-sector applications of mathematics and statistics offer crucial insights into the extent to which occupational hierarchies within disciplines and social hierarchies like gender and nationality operate in tandem. Each of these four disciplines provides different types of opportunities for individuals with varied types and levels of postsecondary training ranging from certifications to doctorates. As the degree level increases in each of these fields, the intellectual content of the work also increases, with less time spent manipulating things and more time spent manipulating ideas and data. In addition, these higher-level manipulations often involve synthesizing information from multiple sources and producing knowledge rather than things. Therefore, while workers are needed at all educational levels, the most powerful roles in these fields typically are played by those with more advanced training. The challenges highlighted in this

[1] Some studies also include the social sciences, which reflect different representational patterns.

volume provide a mirror for the problems generally understood as relevant to the participation of women in science and, also, offer a promising framework for more detailed and comparative investigation of gendered relations and outcomes in other disciplinary contexts.

The volume is divided into three parts. Each chapter includes additional pieces—case studies, profiles, and reflections—contributed by scholars and analysts from around the world, which call attention to the importance of context in understanding women's participation in science. Just as the overall volume explores the interplay among individual, national, and international aspects, so too do these "vignettes" offer insights into multiple levels of analysis in answering questions about women in science. The cross-national insights offered by these pieces provide additional depth to the material in each chapter, adding to an understanding of both the role of gender as an organizing principle of social life and the relative position of women in science within national and international labor markets.

The chapters in Part I lay the foundation for the book, providing an overview of trends in women's representation in science education by global regions, analytical techniques for examining gender in the workforce, and a review of available data on gender and science. Francisco O. Ramirez and Naejin Kwak (Chap. 2) examine 40 years of women's enrollments in science and engineering fields in 69 countries that are aggregated to six world regions. They find that, while women's participation in science and engineering has increased, the terms of that inclusion are still subject to wide variation and debate. Lisa M. Frehill, Alice Abreu, and Kathrin Zippel (Chap. 3) provide a critical literature review and overview of relevant work that has been done to date by demographers, sociologists, and economists on occupational segregation, as an important toolkit for gender analysis. Wendy Hansen (Chap. 4) offers a global perspective and assessment on applicable education and workforce data. Gaps in data collection are identified with an eye to informing policy decisions. Even with various international efforts dedicated to such issues, it is still the case that multiple sources of data must be consulted to "cobble together intelligence" for advocates and policy makers.

Part II considers each of the four exemplar disciplines. Women in the chemical sciences are discussed by Lisa Borello, Robert Lichter, Willie Pearson, Jr., and Janet L. Bryant (Chap. 5). Mathematics is covered by Cathy Kessel (Chap. 6) and statistics is considered by Lynne Billard and Karen Kafadar (Chap. 7). Finally, computing is addressed by Lisa M. Frehill and J. McGrath Cohoon (Chap. 8). While current data are included for illustration purposes, these chapters explore education and workforce situations in each discipline within the overall organizing framework for analytical reference and insight. Each discipline is examined relative to different outcomes and strategies that reflect and impact women's involvement in the given field and the structure and content of the work itself. By focusing in more detail on these disciplines, the specific aspects of the international labor market, distributional differences across national contexts, and within-field structures and relationships along gender lines are examined relative to the interplay of globalization, the social organization of science, and gender relations. As such, these chapters offer starting points for researchers to conduct more nuanced analyses of gender within each field (cf. Creager et al. 2001).

Part III examines the ways in which policies and programs can affect "who will do science." Daryl Chubin, Catherine Didion, and Josephine Beoku-Betts (Chap. 9) describe programmatic efforts as means to address issues of ethnic and gender equity in access and advancement within scientific professions. The authors caution us to be mindful of different expectations for programmatic interventions held by different stakeholders to understand the relative "success" of such interventions. Finally, Cheryl Leggon, Connie L. McNeely, and Jungwon Yoon (Chap. 10) engage related policy issues in terms of who needs to do what, when, how, and for how long to advance the representation and status of women in science. Rather than looking to the behaviors of individual women,[2] their focus is on institutions and governments as loci of intervention for increasing diversity and broadening participation. They point out that policy makers need to be informed by a more detailed understanding of the complex role of gender—as well as other dimensions of difference—in science education and workforce outcomes.

A postscript is offered at the end with thoughts about looking forward and building on the foundation provided by this volume. With multiple audiences in mind—scholars, educators, employers, analysts, policy makers, and other stakeholders—the postscript delineates an agenda for future research, policy, and activism associated with advancing women's participation in science around the world.

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[2] As in volumes that use biographies of women to articulate how women as active agents have surmounted obstacles to gain success in science (e.g., Rossiter 1995; Tang 2006).

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Part I
Cross-Cultural Foundational Issues

Chapter 2
Women's Enrollments in STEM in Higher Education: Cross-National Trends, 1970–2010

Francisco O. Ramirez and Naejin Kwak

Much of the earlier literature on women and higher education emphasized the dearth of women therein. This phenomenon was problematized for three reasons: higher education was increasingly seen as an important determinant of individual adult success; the human capital developed in higher education was increasingly seen as necessary for national success; and, women were increasingly seen as individual persons with rights and with human capital potential. Numerous studies showed that one's life chances were improved as a function of higher education attainment. In sociology, occupational status attainment studies were replicated across a wide range of national contexts. A positive association between higher education attainment and occupational status was reported repeatedly (see for example the papers in Shavit and Blossfeld 1993).

A different but related line of research began to emphasize the importance of education for national economic development (see Harbison and Myers 1964 for an early study). Schooling, it was argued, was the key to developing more productive individuals, and in the aggregate, more productive countries. If individuals needed more schooling to better advance themselves, countries needed more educated individuals to further national progress. Thus, there was a sense that the individual self-interest and the public good of the national society were closely aligned. This new sensibility extended to higher education and undercut older fears about overeducated individuals and societies with too many dangerously underemployed graduates (Freeman 1976).

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Not surprisingly, the earlier studies did not include women in the samples of individuals whose life trajectories were examined. A traditional gendered vision of society, with men in the workforce and women at home, still had some currency in the decades after World War II. But the world was changing albeit slowly. Women's social movements had earlier led to their gaining the franchise throughout the world (Ramirez et al. 1997). These movements globalized women's issues long before the term globalization became ubiquitous in the social sciences. Issues of women's rights increasingly centered on access to domains that were once monopolized by men. Access to higher education became one such important issue (Sewell 1971; Karen 2000). As women gained greater access to higher education, the status attainment and the human capital research traditions evolved to examine the influence of women's higher educational attainment on their subsequent occupational attainment and earnings. Earlier studies of the impact of women's education on their husbands' occupational attainment would not be replicated. The traditional line of research on the effect of women's education on the welfare of their children would continue, but more research now examines the influence of women's education on their own life chances, their wages, and their health, for example. As a gendered vision of society fades, women enter into these studies as individuals rather than as wives or mothers.

These issues are now revisited with a strong focus on women in science, technology, engineering, and mathematics (STEM). In one sense, these are not new issues: the publication of "A Nation At Risk" (1983) dramatized the relatively lower standing of American students in international mathematics tests. A more recent publication of "Rising Above the Gathering Storm" (2007) is also centered on STEM domains. There is considerably less interest in how American students fare in reading tests or in the mastery of foreign languages. Mathematical and scientific literacy are clearly privileged in the national crisis discourse that permeates both of these government reports. A general emphasis on higher education is now shifting to a more specific focus on STEM. The underlying assumption is a straightforward extension of the earlier logic regarding higher education: individuals and societies will both benefit from the enhanced competency and the greater number of students in STEM.

The scholarship, consequently, turned their attention from women in higher education to women in STEM. This is true not only in the United States but also throughout the world. In the West, for instance, it is argued that women have a right to expanded access to STEM and that it is in the national interest to develop policies to improve access to STEM for women. This is an equity issue: what is good for men is good for women. But it is also an efficiency issue: the underutilization of female human capital undercuts national development. Thus, the European Technology Assessment Network (2000) invokes both themes of equity and efficiency in making the case for mainstreaming gender in science policies. Much of the literature on women in STEM is country specific (but see Ramirez and Wotipka 2001; Wiseman et al. 2009). The literature addresses individual and organizational factors that influence the likelihood of women entering into and graduating from these fields of study. This literature is important in its own right and its core finding is that fewer women in these fields are not due to lower ability (Riegle-Crumb et al. 2012). However, it does not directly address the changing global context within which the issues of women in STEM have been generated. In what follows, we briefly sketch a macro-sociological world society perspective and its implications for understanding the worldwide changing status of women. This perspective informs the questions this chapter addresses regarding women in STEM and our discussions of cross-national trends that constitute our basic data.

2.1 World Society and Women's Status

The idea that nation-states operate in a global environment is now almost a commonplace understanding in the social sciences. It is widely understood that nation-states are subject to a large number of transnational influences and that, as a result, there are growing similarities among nation-state structures and policies (Meyer et al. 1997). These transnational influences are applauded when they lead to an expansion of the rights of persons, as in the human rights literature (Hafner-Burton 2013). But they are critiqued when seen as undermining national autonomy and integrity, often found in critiques of the impacts of the International Monetary Fund (IMF) on education, for example (Beech 2011). The problem, of course, is that some of what adds up to national or cultural autonomy may be precisely what impedes the extension of rights to women. For instance, local male dominant cultures may restrict women's educational opportunities through harassment practices that make it dangerous for girls to go to schools and universities, in Taliban-dominated areas, for example.

Globalization has been discussed as a force that has led to nationalism, an invention that diffused around the world as blueprints of nation-building and lead to more similar forms of imagining oneself as a territorially based national entity. From the outset, what now appear to be natural nation-states forged their common identities with transnational blueprints in mind:

> …the independence movements in the Americas became, as soon as they were printed about, 'concepts,' 'models' and indeed 'blueprints.'…Out of the American welter, came these imagined realities: nation-states, republican institutions, common citizenships, popular sovereignty, national flags and anthems, etc. … . In effect, by the second decade of the nineteenth century, if not earlier, a 'model' of the independent national state was available for pirating (Anderson 1991: 81).

This is the first premise that motivates the world society perspective: nation-states derive their identity and their legitimacy from world models of the nation-state. The second premise is that the individual person is increasingly placed at the center of attention within the nation-state (Beck 2002). The idealized nation-state is one that incorporates more diverse segments of its people, transforming them into national citizens. This logic of inclusion can be viewed as an extension of the category of individuals who have rights. It can also be viewed as an expansion of the category of individuals whose development counts toward national development. The patriotic and productive citizen is thus linked to the idealized nation-state.

The third premise is that schooling arises and expands as a favored mechanism for the production of patriotic and productive citizens. Through schooling, peasants become Frenchmen, the working class becomes English or German, and so forth. Mass schooling spreads worldwide, and more recently higher education becomes more accessible to a broader array of individuals. The ideal nation-state is expected to expand schooling and to enact policies that make education a centerpiece of national policy.

The status of women changes in a world where they are increasingly seen as persons and citizens and where women's development is seen as their right as well as an important part of the national interest. Women's movements gain legitimacy from world models of the legitimate nation-state, and at the same time, these movements reinforce and modify the models, highlighting gender-related issues. Thus, various types of gender inequalities are likely to be viewed as inequities and become the object of intense public scrutiny. A growing number of changes in access to education, health, and work are facilitated by global egalitarian standards. In fact, there is ample evidence of changes in the direction of greater gender equality across many domains, including education, mortality, economic activity, and political representation (Ramirez et al. 1997; Paxton et al. 2006; Dorius and Firebaugh 2010).

From the world society perspective, one would expect to find that women have increased their numbers in higher education in general and in STEM fields in specific. But is this indeed the case? This chapter describes cross-national trends in women's share of science, technology, engineering, and mathematics enrollments for about 70 countries between 1970 and 2010. We do so to answer two questions: (1) what is the overall global trend regarding women's entry into these fields of study, and (2) are some fields more women accessible than others?

In what follows, we first examine cross-national trends to answer these questions. We then discuss the main findings. In doing so, we link these findings both to the world society perspective and to feminist arguments that distinguish between women in science and women and science. The core assumption underlying these arguments is that there is more to gender equality than increased female access to domains formerly dominated by men (e.g., Stromquist 2013).

2.2 Cross-National Trends

To describe worldwide historical trends in women's enrollments in STEM fields of study in higher education, six indicators are examined in this chapter. First, to depict a broad picture of women's participation in higher education, we examine (1) women's enrollments in higher education divided by the appropriate postsecondary education age cohort, and (2) women's enrollments in higher education divided by total enrollments in higher education. The first indicator reflects the degree to which women relative to their age appropriate population are enrolled in higher education. National policies that emphasize the need for fully utilizing human capital typically focus on the first indicator. The second indicator captures the degree to which women's presence is increased in higher education relative to men. Scholarly discussions about gender equity often pay attention to this indicator.

Given that much of the current literature is now focused on women in STEM, we next examine (3) women's enrollments in STEM fields of study divided by total enrollments in the fields. Although the natural sciences and engineering may share attributes that make them different from other fields of study, each also has a distinct academic culture, possibly leading to divergent female enrollment trends. Thus, we further examine natural sciences and engineering separately by using (4) women's enrollments in natural sciences divided by total enrollments in natural sciences, and (5) women's enrollments in engineering programs divided by total enrollments in engineering programs. Lastly, we present additional information on (6) total enrollments in STEM programs divided by total enrollments in all programs. We do so to see whether the STEM share of higher education is on the rise and whether that is related to changes in women's share of STEM over time.

The data on women's enrollments in higher education by sex, field, and country were gathered from various volumes of the UNESCO Statistical Yearbook for earlier years (UNESCO 1970–1998) and the online database of the UNESCO Institute for Statistics for more recent years (UNESCO 1999–2010). UNESCO uses the International Standard Classification of Education (ISCED) system to categorize higher education institutions by levels and students by fields of study (i.e., STEM). Three levels of higher education (i.e., vocational, university, and postgraduate) are all included in our analyses. With regard to fields of study, we took into account some changes in the ISCED system during the period under our examination. For example, in some years, the enrollment data on math and computer science programs were collected separately from natural science. We kept the measures of women's enrollments in science and engineering consistent by including math and computer science in natural science throughout the 40 years. There is another issue to note in using the UNESCO data. In some years, a small number of countries provided the overall enrollment information on natural science and humanities together. These cases were coded as missing.

In what follows we first examine historical trends of female participation in higher education in general, and then focus on women in science and engineering fields of study. The sample includes 69 countries throughout the world from 1970 to 2010.[1] UNESCO collects higher education enrollment data from national governments around the world on a yearly basis, but not all governments have participated in data collection every year. The countries missing any indicator listed above for more than 3 years out of the five time points (1970–2010) were eliminated from the sample. This led to the inclusion of 52 to 68 countries in the sample over the four

[1] Our analyses are based on five data points largely around 1970, 1980, 1990, 2000, and 2010. If data were missing, we went on to use information from adjacent years. More than 90% of the data were collected within a five-year window.

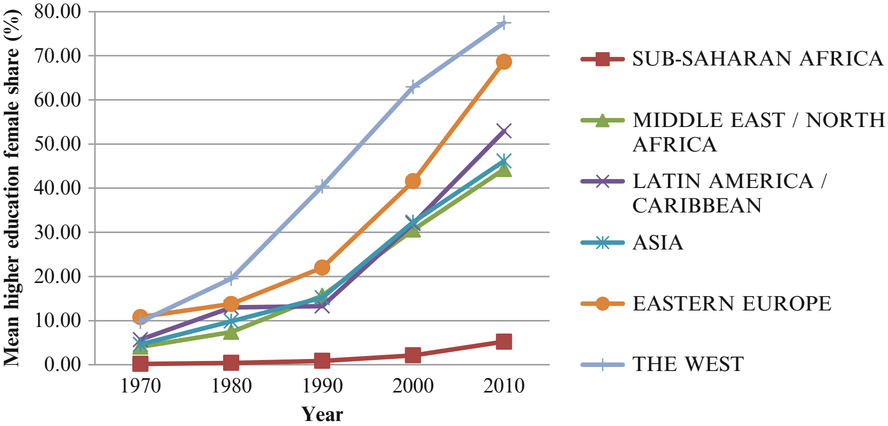

Fig. 2.1 Women's participation in higher education, 1970–2010. *Note*: Data are from various volumes of the UNESCO Statistical Yearbooks (1970–2010). Women's participation in higher education was calculated by dividing the total enrollment of women in higher education by the appropriate school age population

decades.[2] Whereas the general enrollment data were available for a large number of countries throughout 1970–2010, the enrollment data broken down by fields of study were found in a fewer number of countries, particularly in the 1980s and 2000s. Although the West (including Australia and New Zealand) is overrepresented, the countries in the sample vary by level of economic development, type of political regime, and other sociocultural characteristics. The sample covers a wide range of national entities across different regions.[3] The complete list of countries in the sample can be found in the Appendix.

Figure 2.1 plots the degree to which women in the appropriate school age cohort are enrolled in higher education. Regional means are reported for each time point, from 1970 to 2010. We find that there has been a significant growth of female participation in higher education throughout the world for the past four decades. In every region of the world, the percentage of women in higher education in 2010 is greater than that in 1970. This finding is consistent with prior studies that showed a worldwide growth of women's participation in higher education in earlier decades (Kelly 1989; Bradley and Ramirez 1996; Ortega 2008). To be sure, there are some cross-regional differences: women in Sub-Saharan African countries undergo a more modest increase relative to the marked gains in the other regions. As of 2010, more than 40% of women in the tertiary age cohort are enrolled in higher education in countries in every region except Sub-Saharan Africa.

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[2] For example, the United States is excluded from the sample because, for the 1980s, 1990s, and 2000s, the US enrollment data were not reported to UNESCO.

[3] The regional categories in the analyses speak more to sociocultural rather than strictly to geographical categorization.