1 Introduction

Gender Equity in STEM in Higher Education: International Perspectives on Policy, Institutional Culture, and Individual Choice

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Even before the global pandemic of 2020, people across the world faced unexpected challenges and hardships, often surrounding issues of climate change, poverty, and human rights. Carbon emissions that fuel climate change reached new heights in 2019 and, while decreasing during the pandemic-induced slowdown, are expected to return to high levels worldwide (Lindsay, 2020). Poverty projections indicate the COVID-19 economic crisis will more severely affect countries that are already struggling with high poverty rates and numbers of poor (The World Bank, 2020). Estimates show that COVID-19 could force over 70 million people into extreme poverty, with close to half of them found in South Asia and more than a third in Sub-Saharan Africa (The World Bank, 2020). More social movements and activism for human rights have been observed in the world. In the United States, for example, the Black Lives Matter movement has expanded and grown, and students and faculty have protested together against police brutality, White supremacy, and the endless injustices faced by the Black community (Flowers, 2020).

Everything that happened before and during (potentially after) the COVID-19 pandemic has called us to reflect upon what these events mean to women, and particularly women in science, technology, engineering, and mathematics (STEM) education and the STEM workforce across the world. Even before the pandemic, women faculty who had children were more likely to serve as primary caregivers at home than their men partners (Bianchi et al., 2012). Thus, it is not surprising that COVID-19 has diminished research productivity among STEM women faculty and researchers who have young children (Krukowski et al., 2020). A recent study also shows that women faculty in more advanced stages of their careers submitted proportionally fewer manuscripts than men colleagues during the COVID-19 lockdown periods (Squazzoni et al., 2020). Women college students, particularly ethnic minority and low-socioeconomic (SES) women, have faced similar obstacles since they were obliged to stay home and shelter in place (Morabito, 2020). Because of gendered norms, women may have more expectations to help with household labor or care for younger siblings (Sy & Romero, 2008), while at the same time suffering a lack

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of resources and access to technology and learning. We do not attempt to argue who has been the most victimized by the pandemic, because we all have suffered to a certain degree. Rather, we recapitulate the relevance of this book during the period of COVID-19 and the time it takes to recover from its impact. We therefore shape the Introduction and Conclusion of this book to be more reflective of the COVID-19 era.

Our Motivation and Volume Title

When we proposed this book to Routledge in early 2020 (not anticipating a pandemic), we were motivated to contribute to international efforts to improve gender equity in STEM by emphasizing the role of STEM undergraduate education. This volume is timely and internationally relevant based on the United Nations' (UN) 2030 Agenda for Sustainable Development (n.d.). Building on the success of the Millennium Development Goals, the UN's fourth Sustainable Development Goal (Quality Education) sets targets to "ensure equal access for all women" and to "eliminate gender disparities in education." Additionally, the fifth Sustainable Development Goal (Gender Equality) is to "achieve gender equality and empower all women and girls." Similarly, Organization for Economic Co-operation and Development (OECD) countries have implemented initiatives to increase interest in science and engineering among youth (OECD, 2018). The report, *OECD Science, Technology, and Innovation Outlook 2018*, devotes a chapter to gender inequalities in STEM from primary education to careers (Chapter 7). The report confirms that gender disparities in STEM persist even though most OECD countries have implemented a variety of policies to address them. We seek to inform scholarship and practice through the next decade as international organizations and national governments make and document their progress toward achieving Sustainable Development Goals related to gender equity in STEM by highlighting the contribution of STEM undergraduate education for women.

This book, *Gender Equity in STEM in Higher Education: International Perspectives on Policy, Institutional Culture, and Individual Choice*, is the result of international and collaborative efforts to shed light on national-, institutional-, and individual-level efforts to recruit and retain more women through STEM undergraduate education. A discussion of each title word follows, in order to share what motived us to initiate this volume.

Why Equity? We choose the term gender "equity," rather than "equality." Over the past four decades, policy analysts, policy makers, government officials, scholars, and educators have used equity and equality interchangeably (Espinoza, 2007). However, some scholars claim these two concepts have important distinctions in terms of goals and purposes (see Espinoza, 2007). We stand for pursuing gender equity in STEM as defined by Samoff when he describes "equity" in relation to schooling. Samoff (1996, as cited in Espinoza, 2007) explains: "Achieving equality requires insuring that children [students] are not excluded or discouraged from the tracks that lead to better jobs because they are girls" (p. 346). Conversely, "Equity, however, has to do with fairness and justice" (Samoff, 1996, as cited in Espinoza, 2007, p. 346). Samoff argues that *equality* is necessary, but not sufficient, for pursuing *equity*.

> And there is the problem … [Indeed] where there has been a history of discrimination, justice may require providing special encouragement and support for those who were disadvantaged in the past … To achieve equity—justice—may require structured inequalities, at least temporarily. Achieving equal access, itself a very difficult challenge, is a first step toward achieving equity. (Samoff, 1996, as cited in Espinoza, 2007)

We seek to approach ways to change structured inequalities against women in STEM, which requires an understanding of the history and context of each country and its school systems. Our chapter authors aim to offer not only individual- and classroom-level insights but also system- and structure-level implications for promoting gender equity in undergraduate education and ultimately throughout STEM education and the STEM workforce. Although the title uses the term *equity*, our chapter authors use both *equity* and *equality* when explaining the context of their countries' national policies and institutional practices.

Why International Perspectives? Gender inequity in STEM higher education is not only a national issue; it is a global phenomenon (Ramirez & Wotipka, 2001). A series of reports have shown that women remain significantly underrepresented in certain areas of STEM disciplines, such as such as engineering, computer science, physics, and mathematics or statistics, even though the proportion of women in higher education has increased across the world (OECD, 2018). Despite national-level initiatives and investment, gender inequity in STEM disciplines has persisted in most countries. The goal of this volume is not to present which country has better (or worse) initiatives to improve gender equity. Rather, we asked chapter authors to demonstrate the different historical, societal, and cultural aspects of those endeavors to better understand national policies and institutional practices to increase the number of women in STEM higher education. Recognizing the national context is necessary for policy makers and scholars to learn about *unique, but potentially transferable*, policies and practices for supporting gender equity. In other words, we hope readers will consider whether successful policies and practices in one country may work in other contexts.

Why Policy? For decades policy makers and scholars have offered numerous interventions to broaden women's participation in STEM fields throughout primary, secondary, or tertiary education—and ultimately in the workforce. Yet most countries still face concerns about gender in STEM fields. National governments in many post-industrial countries have issued policy reports and implemented educational initiatives policies due to concerns about the lack of parity in STEM and its effects on economic development (Wotipka & Ramirez, 2003). While these efforts to improve STEM education and national development would not be achieved without securing more future women scientists and engineers, scholars have claimed that gender equity should be an equally important mission in and of itself (Barton, 2003; Baillie & Pawley, 2012). This book shows, for each country case, how national policies are shaped and implemented to achieve these two missions.

Why Institutional Culture? We need a culture in science that encourages women to not just choose to enroll in STEM, but that also supports them to persist to graduation and to apply their expertise in the workforce. One of the key reasons that women do not persist in STEM is the combined effects of a "chilly," "weed-out," and "masculine" culture of STEM, which favors men from middle- or upper-income backgrounds. STEM pathway or pipeline studies have shown that culturally responsive curricula and pedagogies, same-gender faculty mentoring, inclusive interactions with peers, and networks and women role models through professional associations are crucial factors to promote retention of women in STEM fields (e.g., Gonsalves, 2011; Gonzalez et al., 2021). We seek to broadly capture how efforts for STEM gender equity among faculty, administrators, leaders from professional associations, and STEM industries can influence and improve the culture of institutions and STEM disciplines.

Why Individual Choice? We asked our chapter authors to provide an account of the experiences and choices that individual women make as part of their everyday challenges and opportunities as they participate in STEM higher education. Rather than reiterating that there are few women in STEM, some chapters reveal successful stories of women students who choose and stay in STEM disciplines. Chapter authors also address how individual women students' psychological (e.g., aspiration, motivation, or interests) and family- and school-level factors affect their choice of STEM subjects or majors in higher education. Furthermore, our authors supply empirical evidence of how women students beat the low odds of completing STEM four-year degrees through the telling of their experiences inside and outside classrooms on campus.

Organization of the Volume and Overview of Chapters

In this volume, we seek to bridge the macro (international/comparative studies)-to-micro (student-focused research) gap to better understand and approach women undergraduates who study STEM in higher education. We divide the book into two parts. Part I of the volume begins with a chapter that provides an international overview of access and success for women in STEM undergraduate programs, which is followed by four country case studies (China, Taiwan, the United States, and England). The chapters in Section One address demographic trends and national policies that affect gender equity in STEM at four-year higher education institutions (for example, educational expansion, national examinations and stratified admissions systems, and government funding initiatives). The chapters in Part II of this volume examine six other countries (Chile, Germany, Kazakhstan, South Africa, Australia, and Hong Kong) and focus on individual-level women's choices and experiences within certain university contexts (e.g., sub-STEM disciplines, curricular and co-curricular programs, and faculty roles). Although we divided the two sections by empirical foci, both sections address national-level policies, broader socio-historical contexts, and access and success among women undergraduates in STEM. Each chapter offers the context of the country, attempts to highlight unique but potentially transferable policies, institutional culture and practices, empirical evidence including quantitative and qualitative data, and implications for increasing gender equity in STEM at the individual, institutional, and national levels. In the conclusion chapter, we offer suggestions for policymakers and STEM educators who wish to learn from successes in other countries. We also discuss how STEM programs in higher education are situated within a context of changing economic, political, and social norms and suggest directions for innovative research and policy for gender equity in STEM fields in the 21st century.

In Chapter 2, “A Cross-National Analysis of Women Graduates with Tertiary Degrees in Science, Technology, Engineering, and Math, 1998–2018: Commonalities and Variations,” Lee et al. conduct a cross-national analysis of 143 countries and territories to examine women’s global participation in STEM. The chapter focuses on women’s share of STEM graduates to explore trends and compare women’s enrollment in STEM to men’s enrollment in STEM and to higher education in general. Lee et al. begin the policy discussion by indicating institutional- and government-level practices that can be adopted to increase women STEM graduates. The authors conclude by highlighting the need to increase women’s participation in the STEM labor market for increases in women’s participation in STEM higher education to have effects on economic development.

Chapter 3, “The Rise of Women in STEM Higher Education in China: Achievements and Challenges,” furthers the discussion of policy by providing an account of how China’s government-level policies promoting gender equality in education in general, and STEM in particular, have increased women’s participation levels. Policies for compulsory education and enrollment quotas are discussed in the context of women students’ learning experiences and labor market outcomes. Similar to Chapter 2, Lingyu et al. note that women college graduates remain at a disadvantage in the labor market relative to men.

Chapter 4, “The Higher Education Trajectories of Taiwanese Women in STEM: A Longitudinal Analysis,” focuses on the expansion of higher education in Taiwan as it relates to the improved participation of women in STEM tertiary education and in the STEM labor market. Despite expanded opportunities, Fu et al. find evidence that women in Taiwan are still likely to self-select out of STEM during upper secondary and tertiary education and that expansion itself is insufficient to achieve equity. The authors acknowledge that policy is only one of many available tools and suggest it may be important to consider individual-level reasons women students may have for self-selecting out of STEM, even though policy initiatives have successfully addressed certain “leaky pipeline” issues.

In Chapter 5, "STEM Bachelor's Degree Attainment among Women of Color in the United States: Using Geographic Analysis for Gender and Racial Equity Research," Ro et al. delve into the ways the number of women of color residents who obtain STEM bachelor's degrees varies by access to local higher education opportunities. The authors also incorporate a discussion of additional challenges women of color face that exacerbate the structural barrier of geographic disparity in educational opportunities. Strategies to combat these challenges and facilitate the success of women of color range from institutional level practices to national level policies.

In Chapter 6, "A Comprehensive Approach to Addressing Gender Equity in STEM Subjects at Four-Year Universities in England," Ro et al. study gender disparity in undergraduate STEM enrollment in England, including enrollment at prestigious Russell Group universities. The authors locate this discussion within the context of the expansion of higher education in England and a consideration of differing social classes and academic backgrounds of women students who pursue STEM subjects in higher education. The authors claim that more research should examine how the relationship between STEM subject choice and the selectivity of institution admission varies by gender.

Chapter 7, "Women in STEM in Chilean Higher Education: Social Movements and Institutional Transformations," begins our conversation about individual-level factors and women's choices and experiences in STEM. Kim and Celis provide an account of social and intellectual movements in Chile that improved policies and participation in higher education for women, such as increased representation in faculty and leadership positions and an increase in STEM majors. The authors address how women have experienced discrimination and stereotyping in Chilean society and remain underrepresented in STEM by analyzing historical enrollment data. The authors posit that recognizing and replicating how women are recruited and retained in STEM majors will further improve women's STEM representation, especially those policies that have worked so well in Chile.

In Chapter 8, "Examining Gender (In-)Equality in German Engineering: Considering the Importance of Interest, Perception, and Choice," Dusdal and Fernandez focus on the persistence of gender inequality in undergraduate engineering education in Germany by analyzing individual factors that contribute to women's tendency to consider but then opt out of engineering. Similar to Chapter 7, the authors provide strategies to facilitate success and increase participation such as policy initiatives to recruit and retain women students to STEM and to support parents and teachers for early intervention.

In Chapter 9, "Gender Equity in STEM in Higher Education: Kazakhstan," CohenMiller et al. describe three challenges to gender-based equity in STEM in a post-Soviet context and offer multiple policy suggestions for improvement. The authors highlight ways that legal and political reforms have benefited women but have not changed cultural norms and expectations for women that influence their opportunities and their decision-making in STEM education and employment. CohenMiller et al. examine the pipeline in Kazakhstan, which shows "leaks" in recruitment and promotion in academia and employment for STEM students, graduates, and faculty.

In Chapter 10, "Black African Women in Engineering Higher Education in South Africa: Contending with History, Race and Gender," Mlambo describes women's higher education in South Africa, with a focus on Black women engineers, and underscores how they are discouraged from pursuing engineering degrees and academic careers. Black women in South Africa "experience higher education as racialized and gendered" and interact with institutions and a higher education system that is mostly White. The author offers numerous suggestions for making higher education and engineering both more welcoming for Black women and for dismantling the culture of whiteness within South African higher education.

In Chapter 11, "Approaches for Attracting, Retaining, and Progressing Women in Australian Undergraduate Engineering: Curricular Innovation Focused on Humanitarian and Human Centered Design Concepts," Goncher and Cameron illustrate how collaboration between stakeholders, such as academia, government, and industry, and across programs aids in the recruitment and retention of women students and faculty in engineering. Utilizing Australia as an example, the authors advocate for a cohesive message to promote gender diversity in STEM and higher education.

In Chapter 12, "Aspiring and Becoming STEM Teachers in Hong Kong: A Gender Perspective," Tang et al. focus on the importance of teacher education for inspiring pre-service STEM teachers. Their chapter offers insights about the critical role pre-service STEM teachers have in the classroom to provide professional training, avoid gender stereotyping against students, and act as role models for a more gender equitable future in STEM. The authors used educational ethnography methods to interview pre-service women teachers majoring in STEM-related programs at the largest teacher training university in Hong Kong. They recommend policy changes for deconstructing gender stereotyping and diminishing gender disparities to achieve justice in STEM teacher education.

For Our Readers

Gender Equity in STEM in Higher Education: International Perspectives on Policy, Institutional Culture, and Individual Choice takes an international and comparative approach to examining gender equity in STEM fields at the undergraduate-university level. The two sections of the volume allow us to organize chapters based on two themes: those that primarily focus on national policy initiatives and those that primarily focus on women's agency and choice. This volume brings together experts from around the world to identify *unique but potentially transferrable* implications for increasing gender equity—that is, to not only describe the successes of a single country but to consider whether policies and practices to support gender equity in STEM may work in other contexts.

We want to circle back to where we started in this chapter: by calling for readers to consider gender equity in the wake of the COVID-19 pandemic. The pandemic offered a compelling narrative about the importance of women and internationalization in STEM, specifically, in vaccinology (Bora, 2020; Wadman, 2020). Dr. Nita Patel was born in India and has led an all-women team of scientists at Novavax Lab in the United States, which has been at the forefront of developing a COVID-19 vaccine. One member of Patel's team, Dr. Sonia Maciejewski, previously made productive and valuable contributions to vaccine development to address the international threat caused by the Zika virus (Maciejewski et al., 2020).

The story of women scientists developing vaccines to address a global pandemic was inspiring during the difficult period we spent compiling this volume (particularly because all of us have daughters). During and after the COVID-19 pandemic, we believe that women like those who work on vaccines will continue to support future women scientists and engineers. Women have been underrepresented in STEM in the past, and we worry that the pandemic's social and economic impact is disproportionately affecting women and could disrupt progress toward gender equity in STEM. We hope this volume will offer implications not only for individual-level efforts but also institutional- and national-level commitments to improve gender equity in STEM through undergraduate education.

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