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Unique but Transferable Approaches for Pursuing Gender Equity in STEM in Higher Education across the World

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We collaborated to compile a volume that offers nine country case studies and one comparative study devoted to improving gender equity in STEM through undergraduate education. At the end of this volume, we seek to synthesize findings from across chapters to think about improving gender equity in STEM at the individual, institutional, and national levels. We also hope to offer suggestions for how policy-makers and STEM educators may apply unique but potentially transferrable strategies presented in this volume. Finally, we suggest directions for innovative research and policy for pursuing gender equity in STEM fields after the economic and educational turmoil caused by the COVID-19 pandemic. We suggest five recommendations for future research, as well as for national- and institutional-level policies.

While we synthesize lessons from each chapter, we cannot help but revisit the social and economic impacts of COVID-19 on our life and on the contributions of women in STEM areas. Science and innovation are even more important in our life as demonstrated by their indispensable roles in providing a better scientific understanding of the virus, as well as in the development of vaccines and diagnostics treatments. And, as mentioned in the introduction, women scientists have been at the forefront of innovation and solutions, as the example of Dr. Patel and her team illustrate.

The OECD (2021) indicates science and innovation policies will face ongoing challenges from multiple, competing demands for finances and resources greatly exacerbated by the pandemic. However, as governments address ongoing challenges, there will be opportunities to reform science, technology, and innovation policy to promote a more equitable STEM landscape. We seek to shed light on how undergraduate education can play a critical role in offering “sustainable, equitable, and resilient futures” by improving the underrepresentation of women in STEM (OECD, 2021).

As with any volume, we reached a practical limit to the number of country case studies we could include in a single work. Though we contributed to the conversation on the need to approach gender equity in STEM as a global challenge, we did not particularly focus on countries with lower levels of gender equality, in terms of inequities in living conditions (e.g., earnings, tertiary enrollment ratio, life expectancy, or seats in parliament by gender).

Therefore, future research should focus on countries with higher economic and general life risks as we explain below. Subsequently, we suggest implications to revise the current national and institutional systems and structures that have reinforced a culture dominated by men in STEM higher education. After that, we claim that scholars and policy makers should consider women STEM undergraduates who hold other marginalized identities. We also offer ways research and policy should extend gender binary to include transgender and nonbinary women's identities and experiences. Fourth, we suggest that researchers and policy makers consider and address equity challenges across STEM sub-disciplines and different types of institutions, rather than aggregating disciplines or institutions. Finally, we discuss what we would anticipate and prepare in order to improve gender equity in STEM after the COVID-19 pandemic era.

Approaching Gender Equity in STEM as a Global Challenge

In this volume, we seek to emphasize the need for studies on access to and success in STEM fields in higher education (i.e., tertiary or postsecondary education) via an international and comparative perspective. However, we could not include all countries which have invested to recruit and retain more women in these fields. Stoet and Geary (2018) identify what they call an “educational gender-equality paradox” (p. 581), drawing upon expectancy-value theory (Eccles, 1983; Wang & Degol, 2013), which suggests that students choose academic paths on the basis of their relative academic strengths (or weakness) and academic attitudes as well as social factors (e.g., economic benefits and risks of a STEM career). Some scholars argue that countries with high levels of gender equality have the largest STEM disparities by gender in secondary and tertiary education. Scholars have claimed that when economic opportunities are higher and risks are less, as with most gender-equal countries, individuals may choose academic and career paths based on their interests and academic strengths (Richardson et al. 2020; Stoet & Geary, 2018, 2019; Wang et al., 2013). In Chapter 2, Lee et al. found a similar pattern across countries and discussed that both men and women students may choose a field of study based on individual preferences in Western society and individualist cultures. This may account for why the Middle East and North Africa region may be more open to women in STEM.

These studies imply that improving gender equity in STEM may not be equivalent to promoting gender equity in the broader society. Future research should address how women who obtain STEM university degrees have affected or promoted women's rights and improved gender norms in countries with both low and high levels of gender equality. In particular, much remains unknown to global readers about how STEM women students and professionals in countries with low gender equality face challenges and fight for women's rights and gender issues in STEM fields and their country. For example, many Middle Eastern countries have endorsed the Convention on the Elimination of all Forms of Discrimination Against Women (CEDAW) and shown a strong

commitment to broaden access to STEM education and workforce for women (Islam, 2019). From the UNSCO and World Bank statistics, Islam (2019) suggests that there is not much gender difference and women even outnumber men in most STEM enrollment and degree attainment in higher education (except engineering). There is still a substantial disparity of women in the STEM workforce considering the percentage of women enrolled and graduating in STEM from higher education institutions.

For future inquiry, more country case studies on gender equity in STEM would help readers better understand the international and comparative outcomes on gender equity in STEM. In particular, Perez-Felkner et al. (2020) acknowledge that few studies have analyzed variation in postsecondary STEM gender gaps *within* developing countries. By analyzing the case of STEM postsecondary education in Cambodia, Perez-Felkner et al. (2020) suggest that researchers should conduct more studies on gendered STEM postsecondary education pathways in non-Western and industrializing country contexts. Our edited volume would offer implications for countries that devote policy to improving the issue of socioeconomic equity and to building human capital by broadening women's participation in STEM education and workforce.

Changing Systems, Not Individuals

Our chapter authors offer glimpses at how national- and institutional-level policies and practices have affected women in STEM fields, particularly in STEM undergraduate education. In this volume, some authors conclude that national policies to broaden women's participation in higher education were successful in their countries; however, the extent to which this occurred was disproportionate across different disciplines. For example, In Chapter 3, Lingyu et al. suggest that government policies surrounding the structure of the population, such as the one-child policy, and the structure of education, such as enrollment quotas, has increased the level of participation in education among women in China. In Chapter 4, Fu et al. write about the expansion of Taiwan's tertiary education system, which improved the participation of women in STEM education and the STEM labor market. Despite expanded opportunities, however, these authors found that women were still likely to self-select out of STEM during upper secondary and tertiary education. In Chapter 8, Dusdal and Fernandez present data from Germany showing that many women may delay decisions about whether to pursue their interest in STEM programs until well into tertiary education and introduces an example of how one university provides faculty mentorship to encourage women to pursue STEM opportunities.

We do not imply that all national-level, government-initiated policies are ineffective; rather, we argue that it is important to recognize that the expansion of educational access for women is not equivalent to STEM educational opportunities for women. Similarly, expanding STEM educational opportunities for women is not equivalent to creating labor market opportunities for women. In

Chapter 11, for example, Goncher and Cameron introduce government-led initiatives, such as the Federal Government's Women in STEM Decadal Plan which develop collaboration across K-12 schools, universities, and industry to increase the number of women engineers in Australia. Reading across chapters, we suggest that developing countries may simultaneously consider educational expansion and STEM pipeline-focused policies. When government-initiated STEM education policies are implemented, researchers and policy makers should conduct follow-up studies to explore not only the impact of those policies but also the motivation that students have to study STEM majors. In Chapter 9, CohenMiller et al. explain that students may choose STEM for financial reasons because grants for STEM majors far exceed grants for other majors. In this case, women who obtain STEM degrees may want to choose other fields for their career if they were not satisfied with their learning, or with the culture of STEM disciplines, or if their major choice was simply a function of the financial realities of higher education in Kazakhstan.

Other authors also shed light on the need to transform systems and structures which have reinforced privilege among men (and ethnic majority populations) and discouraged women from entering and staying in STEM fields. In Chapter 5, Ro et al. emphasize that the local supply of schools offering four-year university degrees and institutions offering STEM degrees are not evenly distributed across the United States (Hillman, 2016). In addition to disciplinary-level challenges, such as microaggressions, stereotyping, alienation, and exclusion, women, particularly women of color, face geographic disparities. More research is needed to examine the geographic disparities in STEM educational opportunities that function as structural barriers. In Chapter 10, Mlambo underscores how Black African women are discouraged from pursuing engineering degrees and academic careers in South Africa. For example, in South Africa, Black African women engineers see academic careers as part of the sexist and racist system they want to transcend and therefore they often decide to work in industry instead. Mlambo describes in her chapter how race-gendered experiences among Black African women engineering students and engineers occur within the context of historical apartheid, the legacy of which is still impacting higher education in South Africa and influencing the decision-making of Black South African women in STEM. She 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 that precipitates a damaging narrative.

Almost all chapters in this volume suggest the importance of women role models and their mentoring and support, as well as networking between women students and professionals. Professional associations, such as the Women in Science and Engineering (WISE) in the United Kingdom, and Women in Engineering ProActive Network in the United States, are good examples. While we value the contribution of women mentors, these programs should not rely on individual women or overburden their service roles. Kwak

and Ramirez (2019) state that these types of programs have been rightly criticized for their focus on changing women, which locates the responsibility on them, instead of a focus on changing structural barriers, which would correctly locate the responsibility on the system. In Chapter 11, Tang et al. found that gender stereotypes have been internalized (e.g., STEM subjects are a better fit for boys than girls) by pre-service STEM teacher education in Hong Kong; thus, stereotypes about women in STEM can be perpetuated by STEM teachers—even women STEM teachers in K-12 education. Developing systems to help individuals identify their own implicit biases against women is necessary to help support women to develop educational and career aspirations in STEM (Bearman et al., 2009).

Better Understanding “Who We Are Addressing as Women?”

We propose scholars and policy makers consider incorporating an intersectionality framework lens in order to better support women students who have other marginalized social identities (e.g., racially minoritized women, low socioeconomic-status women). Anti-racism and feminist scholars argue that incorporating an intersectionality framework in any gender equity work is necessary to dismantle structural barriers against these women who have intersected marginalized identities (Crenshaw, 1989; Collins & Bilge, 2016). Given that intersectionality scholars traditionally address racially minoritized women, some readers may think that this recommendation is more directly relevant in the context of some countries than in others. For example, an intersectionality framework is necessary to understand racially minoritized women in the United States because of double bind barriers (see more in Chapter 5 this volume). Race and ethnicity may not be a salient factor in other countries; however, the framework still offers insights as women students’ social identities and demographic backgrounds are not homogeneous, in terms of their social class, disability, age, sexual orientation, or immigrant backgrounds, in addition to their race/ethnicity. More importantly, the current system of STEM education and workforce may include not only privileged men but also privileged women and exclude women students with minoritized backgrounds (Archer et al., 2017).

We also want to challenge scholars and policy makers to take steps to help create more inclusive environments for transgender and nonbinary individuals who want to study STEM majors in higher education. In this volume we posit sex and gender are different in that *sex* should be used for biological differences between males and female, whereas *gender* should be used for differences between women and men that are developed socioculturally (see Hyde et al., 2019). Even though we believe that gender is a socially-constructed concept, we could not include transgender and nonbinary women. Recently, scholars have investigated how the culture of STEM environments has excluded transgender, gender nonconforming, or nonbinary undergraduates (Haverkamp et al., 2019; Miller et al., 2020). We suggest that more qualitative inquiries are needed to explore these students’ experiences and success in STEM higher education.

Studying the Unique Context of Sub-STEM Disciplines and Different Types of Universities

Institutional types seem to matter for gender equity in STEM fields. Studies often address STEM bachelor's degrees, but do not dig into which types of institutions women tend to choose and complete their degrees at when they study STEM subjects. In Chapter 6, Ro et al. study the gender disparity in undergraduate STEM enrollment in England, including enrollment at prestigious Russell Group universities. After controlling for social class and academic background, women had lower odds of enrolling in STEM than men at Russell Group universities. Ro et al. did not find the same pattern when they did not consider subjects (if they included all students who study both STEM and non-STEM majors) at Russell Group universities. Considering institutional types is critical for low-SES women and racially minoritized women because they may attend institutions which lack resources for experiential learning opportunities, such as internships, undergraduate research, or study abroad programs (see Kim and Celis, Chapter 7 this volume, and Ro et al., Chapter 6 this volume). Policy makers should consider investing in two-year community colleges, technical and professional schools, and minority serving institutions (as in the case of the United States) to better support women to obtain STEM bachelor's degrees and to succeed in the STEM workforce.

Many studies, both international/comparative studies and single country case studies, combine STEM disciplines together. When researchers examine gender equity issues, sub-disciplinary analysis is necessary, since women are overrepresented in biological/natural sciences but underrepresented in physical science, engineering, and computer science, particularly in undergraduate programs, across the world (Kwak & Ramirez, 2019). Combining these two disciplines may elude the nuanced differences by gender in STEM disciplines. Kwak and Ramirez (2019) suggest that more comparative longitudinal studies are needed to examine the experiences of women relative to those of men in different STEM-subfield fields of study across different national contexts.

Post-COVID-19, What Would We Expect for Gender Equity in STEM?

Countries took a lot of different approaches to providing primary and secondary education during the pandemic. Not surprisingly, the ways countries provided opportunities to learn during the pandemic differed by region and country wealth (Vegas, 2020), including internet access. Countries in Sub-Saharan Africa were unable to provide teachers with any training for remote teaching, while more than half of countries in Europe and Central Asia provided training to teachers. In addition to these challenges, the pandemic is also expected to indirectly inhibit women's right to education. According to UNESCO's 2020 Global Education Monitoring Report, child marriages, teen pregnancies, and gender-based domestic violence were projected to have sharply increased during the

pandemic. Girls who dropped out of school during the pandemic were less likely than boys to return.

Historically, scholars have used international datasets to consider how girls are achieving in mathematics. One of the most commonly used datasets is the Programme for International Student Assessment (PISA). For example, Stoet and Geary (2013) analyzed several waves of PISA data to examine differences in boys' and girls' attainment in STEM and to understand how differences vary both within and across countries. As of this writing, the latest wave of PISA data collection was postponed because of the pandemic. At best, future research that will examine girls' preparation for studying STEM will have been disrupted by the changes in PISA data collection. Worse, countries could decline to participate in PISA if budgets are being cut amid competing economic challenges. Although more data will be collected to try to measure the effects of the pandemic, early projections suggest that the disruption to primary and secondary school has led to a decline in mathematics learning (Soland et al., 2020).

At the higher education level, there have been significant declines in women's enrollment at universities. For example, Australia witnessed as women's enrollments in its higher education system declined by more than 85,000 students (Zhou, 2020). Most of the women who dropped out or had to forego enrollment in Australian higher education were older than 25, suggesting that they had competing family responsibilities. The Australian numbers are striking because Australia is ranked highly among other countries in terms of gender equity for women (World Economic Forum, 2020).

In the wake of the pandemic, researchers will need to collect and analyze data to try to measure the effects of the economic and health threats on the pathway for women to study STEM in higher education. Policymakers will need to consider various opportunities so that they do not lose two generations of women in STEM: the girls who are either missing out on primary and secondary school or who are learning less mathematics through distance education, as well as the women who missed out on higher education because of the pandemic. Women will be crucial to international efforts to recover from the pandemic. Even before countries began adopting strict quarantine and social distancing measures, the European Institute for Gender Equality (n.d.) projected that if countries in the European Union (EU) could achieve gender parity in STEM fields, they would create more than 1 million good jobs in the EU and increase per capita GDP across the EU by up to 3% (more than €800 billion).

Conclusion

This volume is the result of collaborative efforts on a research agenda for advancing gender equity in STEM higher education. As editors, we had the opportunity and privilege of reviewing each chapter multiple times. The process of compiling and editing this volume allowed us to develop recommendations for continuing the conversation on how to pursue gender equity in

STEM. While we scrutinize undergraduate education, the STEM pathway begins from early childhood and continues through women's careers. We hope that this work could also offer insights for scholars and policy makers who devote their efforts to enhancing gender equity in STEM in K-12 education, graduate education, and the workforce. We intend that our suggestions will inspire ideas for future scholarship and inform ideas for developing policies among readers. Finally, when we have been reading literature on women in STEM, almost all researchers begin with the observation that women are underrepresented in many STEM fields, and that this is not a single country's problem. We hope that our daughters' generation (currently six years to nine years) would encounter different stories about women in STEM disciplines when they are our age. We genuinely hope that our volume contributes to improving the underrepresentation of women in STEM through higher education.

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