Review Article

Academia and Industry: Challenges Faced by Women in STEM in the Global South vs the Global North

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This chapter offers a detailed comparative analysis of the challenges women face in science and industry, highlighting contrasting experiences from the Global South and the Global North. It emphasizes various aspects of gender gaps and systemic barriers women encounter in these fields. The chapter adopts a metadata-driven approach to examine ongoing challenges and inequalities in both industrial and academic sectors. It begins by analyzing postcolonial patriarchal social structures that create gender-biased opportunities and exclusionary practices. This analysis explores how gender issues, cultural misogyny, and societal divisions contribute to the underrepresentation of women in academia and industry. It then investigates the gender-specific impacts and unique consequences of the COVID-19 pandemic on women. In conclusion, the chapter discusses the effects of these challenges on women and reviews the progress made across different areas. It evaluates how much these issues continue to persist, especially in relation to achieving United Nations Sustainable Development Goal 5: Gender Equality, as part of the 2023 Agenda.

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1. Setting the stage

Pre-existing conditions: a brief historical perspective and modern relevance

A deep-rooted belief in prescriptive differences between the sexes has been a prominent aspect of the global historical narrative surrounding gender roles in both professional and domestic settings[1][2] and results in arbitrary marginalization. Social research confirms that this pervasive dynamic of dismissal is

due to a combination of structural gender stereotypes and subsequent normative behaviors with long historic roots that have a directly limiting effect on female development[3][4]. Ethnicity and the melanin content of skin heighten these biases (Liu et al., 2024). As with all colonial power dynamics, they are more pronounced in the Global South, where women face these barriers with greater intensity, even from childhood. Current manifestations of this centuries-old paradigm of prescribed gender biases are notions like the maternal wall, the ideal worker, the ideal homemaker, and gender-specific fields. This paradigm has cast women as more suited to domestic roles and men as more fitting for intellectual pursuits[5]. An analysis of power dynamics from a historical perspective reveals a universal experience for women in both the Global North and the Global South: social status has been defined by a patriarchy, often through marriage. The binding of women to their husbands as legal authorities is a form of 'contractual servitude' and leaves women's personal development out of their own hands. Current manifestations of these autonomic imbalances, written into normative mandates and even legal frameworks (or left out), are evident in the persistent obstruction of basic resources like money and education, and the subsequent professional advancement of women. As we face extensive and increasing fallout from irrational development and subsequent global warming, the full expression of our social capital is imperative. Gender imbalance is aggravated by intensified resource disparity, leading to an exponential decline in global health.

Historically, societal views have generally portrayed women as the 'weaker sex,' perceived as needing protection from the world's challenges (benevolent sexism), whereas men have been regarded as stronger, more adept, and naturally more fitting for the demands of the workplace[6][7]. In prevailing global narratives, the Global North (GN) is often seen as more progressive than the Global South (GS). This oversight is exemplified by the works of renowned Western liberal thinkers like Jean-Jacques Rousseau, Immanuel Kant, and Thomas Paine. Despite focusing on liberal ideals, emancipation, equality, and justice, these men notably excluded women from their political discourse. For instance, Rousseau's (1762) "The Social Contract" centers on the concept of an ideal citizen, represented by the male character Emile. Rousseau's work extensively discusses Emile's education while significantly overlooking the educational needs of the female character, Sophie, who is relegated to a mere companion role without a second thought. Mary Wollstonecraft's groundbreaking 1789 work, "A Vindication of the Rights of Woman," stands in marked and contemporary contrast to this myopia. In it, Wollstonecraft contends that virtues and excellence ought to be acknowledged on the basis of one's humanity, rather than gender. Her work was never given the renown nor was it integrated into the great male thinkers' work. This shows a

one-sided relativity, historically and currently, around the concept of “progressive.” The evolution of social justice has been inherently limited by gender bias.

There is an indicative anecdote from science historian (and subsequent revisionist) Dr. Margaret Rossiter. In a meeting of male graduate students and professors at Yale in 1969, where she was the only woman in the history of science graduate program, she asked, “Were there ever women scientists?” She recounts that the answer was an "authoritative" and resounding “No,” even discounting Nobel Prize winner Marie Curie. This led her to a study on women in science that would result in three published volumes, with the last book published in 2012. She wrote in her first volume, “*It is important to note early that women's historically subordinate 'place,' in science (and thus their invisibility to even experienced historians of science) was not a coincidence and was not due to any lack of merit on their part. It was due to the camouflage intentionally placed over their presence in science*.” This historical context retains relevance in the current state of women’s professional growth in both the GN and GS. An emblematic example from the 20th century in the GS is Bibha Chowdhuri of India. History completely dismissed her until 2008 in spite of her groundbreaking discovery of a new subatomic particle in 1948—were she recognized, she would have been a Nobel Prize recipient (possibly two), if not for Cecil Powell taking credit...and we will never know if Patrick Blackett used her work for his Nobel[8]. This is indicative of multiple societal dynamics discussed in detail throughout the chapter, and as we will see, Bibha Chowdhuri is far from alone. The consistency and greater intensity we see in these dynamics in the GS as compared to the GN not only underscore the ubiquity of these challenges but also illustrate the varying levels of severity they assume in different parts of the world. There are serious and detrimental implications for the health of humans and the globe in very short order, with the drivers of climate change and poverty being parallel drivers of oppression, discrimination, and exploitation[9].

As a result of these concerns and the global impediment of gender discrimination, the United Nations (UN) developed an international set of 18 Sustainable Development Goals (SDGs) in 2012. The SDGs are a result of the 8 Millennium Development Goals (MDGs) that were not met at the turn of the 21st century. The UN defined sustainable as “*meeting the needs of the present without compromising the ability of future generations to meet their own needs*.” Through extensive international research, UN researchers distilled 18 areas of focus that require action to ensure the sustainability of our future as a species. Gender equality is mentioned in 10 of them. As a result, SDG goal #5 was developed specifically around gender equality: “[The goal is to] *Achieve gender equality and empower all women and girls. Gender equality is not only a fundamental human right, but a necessary foundation for a peaceful, prosperous and sustainable world*.”

Regrettably, according to the most recent UN report on progress toward the Sustainable Development Goals (SDG), not one of the 18 goals is on track for compliance by 2030. In fact, we are far from it:

> "*At the current rate of progress, it is estimated that it will take up to 286 years to close gaps in legal protection and remove discriminatory laws, 140 years for women to be represented equally in positions of power and leadership in the workplace, and 47 years to achieve equal representation in national parliaments. Cascading global crises have highlighted and exacerbated existing gender inequalities, such as unequal access to healthcare, education, and economic opportunities.*"

While the imbalance applies to women's presence and progress in all fields, this chapter will focus on science, technology, engineering, and mathematics (STEM). These systemic obstructions initially impede women's access to STEM education. Once women break through those barriers, there are additional normative barriers to contend with that directly impact access to fair compensation and necessary resources. The further that women pull themselves up the career ladder, the greater the barriers to effectively asserting themselves in all roles[10], resulting in "glass ceilings" and "glass cliffs." Like all social dynamics of gender discrimination, this is intensified as a result of post-colonial constructs[11], which are more pronounced in the GS. The most challenging aspect of these patterns is that they are structural and normative feedback loops that have reinforced themselves for centuries.

These self-reinforcing feedbacks hindering women in today's STEM trajectories starkly reiterate that, without the proactive application of our knowledge, we will simply continue to perpetuate this vicious cycle. In light of this, the current chapter delves into an in-depth examination of some of the hurdles women encounter at various levels of academia, resulting in their underrepresentation in both academic and industrial sectors on a worldwide scale. Simultaneously, we will explore the historical evolution of entrenched gender stereotypes, tracing their development from past to present. Finally, we will make some suggestions as to how to accelerate the progress toward the United Nations' 5th Sustainable Development Goal and greater equality in STEM fields.

2. Laws, Flaws, and ‘Double-Dealing’

Society, Subjectivities, Structure

The global legal framework is set up for systemic prejudice, with gender prejudice impacting approximately half of the global population[12]. The underrepresentation of female perspectives is evident in policies impacting all aspects of women's lives (Hyland et al., 2020). This is graphically depicted in Figure 1[13], which illustrates the levels of discrimination against women around the world, highlighting both the severity and the often underreported nature of these issues. Parks (2021) notes that many countries in the Middle East and North Africa, because of gender-normative behaviors, rank in the bottom percentile of the Georgetown Institute’s 2019 Women, Peace, and Security Index. Syed and Kreide[14] observed that in Iran and Afghanistan, women are still legally considered inferior and are arbitrarily arrested, often for breaching simple societal norms, an example being the “morality police.” Another legal exemplar of this systemic bias is seen in the handling of domestic violence cases worldwide. Despite being a crime that disproportionately affects women, there is a tendency for male perpetrators of domestic violence to receive relatively lenient sentences compared to other violent crimes. Conversely, women who defend themselves in such situations are frequently prosecuted more severely, often without adequate consideration of extenuating circumstances. This happens despite the provisions outlined in Rule 61 of the UN Rules for the Treatment of Women Prisoners that require taking into account extenuating circumstances. The issue is that gender discrimination and abuse perpetrated by men often do not receive full legal prosecution, even within the existing, albeit inconsistent, legal frameworks. This is in part because women's accounts and testimonies are frequently met with skepticism or disbelief[15]. Such iniquities in legal treatment underscore the urgent need for more equitable and sensitive legal policies and practices.

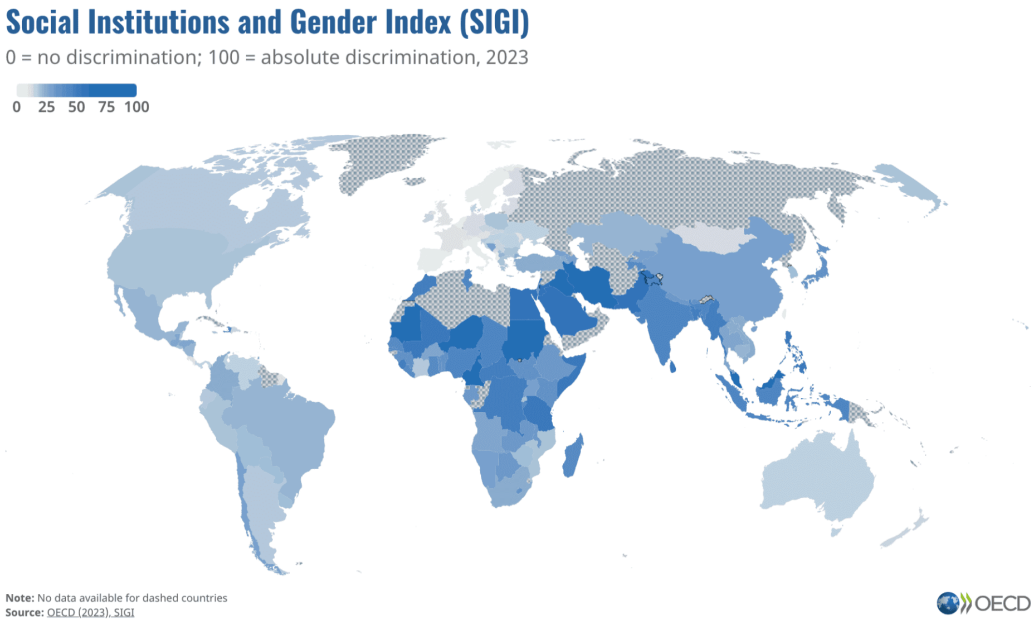

Figure 1. Map of global discrimination levels as presented in the 2023 Social Institution and Gender Index (SIGI) report. Full citation in References.

However, it is impossible to change the systemic limitations for women when women are excluded from the development of the political discourse and subsequent legislation affecting their rights. Krook and True[16] reported, "*Delegates to the UN World Conference on Women in Mexico City in 1975 therefore proposed an expanded definition of 'women's political participation' in the World Plan of Action, noting: Despite the fact that, numerically, women constitute half the population of the world, in the vast majority of countries only a small percentage of them are in positions of leadership in the various branches of government.*" As of 2019, in the vast majority of federal governments, women make up less than half of the governing seats in parliaments around the world. The highest-ranking country, Antigua and Barbuda, showed 52% of its federal governing body was women. Mexico was the second highest with 49% women, followed by Bolivia, Kazakhstan, and Tanzania at 47%, with Burundi and Canada following at 46%. Of 193 countries, 4 countries have 40–45% women and 17 have 30–39% women. The United States had a meager 25%. After that, the percentage drops for the majority of the remaining countries to less than 25%. As of 2019, 113 countries had no women in parliament. UN Women[17] reports that there has been extremely modest improvement.

In a broader context, global economic laws have consistently disadvantaged women throughout the 20th century and into the 21st, reflecting a systemic issue that extends far beyond individual institutions and into the fabric of global economic structures[12]. Despite the existence of financial support mechanisms like scholarships, fellowships, grants, and loans, women around the world continue to face financial barriers when trying to access these resources, impeding their social and professional advancement[18]. Often, women are denied financial support by financial institutions, grant funders, and academic institutions based on their gender and associated markers[18], with little to no legal recourse available to them as this is part of policy.

Access to education has been a pivotal factor in the oppression of women. Historically, from the 5th century BCE up to the 19th century, women were largely barred from participating in higher education, with the exception of those who entered convents[19]. As we will discuss in the section on academia, girls' access to education has been historically underprioritized in the GS[20]. Progress in women's access to education in the GN was seen in the 19th and 20th centuries, as privileged women began to gain more access to education. However, laws and societal norms continued to impede full participation[21]. Notably, many prestigious universities in the GN, including Ivy League institutions, had policies that upheld female subjugation as acceptable[22]. In terms of STEM, women were restricted in the fields they could pursue, constrained by both legal and societal barriers that varied over time[4]. They often faced additional burdens to maintain their educational opportunities, clearly indicating their secondary status. An emblematic example is from Oberlin College where, upon women's initial admission in 1837, female students were required to perform laundry services for their male counterparts on Mondays rather than attend class[22]. Furthermore, for decades after the first admission of women into universities in the GN, they were required to achieve higher performance scores than men for entry, a practice that persisted legally until just before 1972[22][4].

Additionally, in many workplaces, gender-biased practices abound[23][24]. In many cases, 'family-friendly' policies in the workplace often translate into unstable arrangements and significant career penalties written into the rules and bylaws[6][25]. This is often inflamed by the mandatory domestic duties that lead women to take both short-term and long-term leaves, affecting their pay and career progression. Such interruptions in their careers diminish their chances for advancement and networking, which are especially crucial for women in all sectors of STEM[26]. Moghadam et al. [27] explain the low participation rate of women in professional STEM roles (and other sectors as well),

particularly in geographical areas with traditional conservative cultures, as being grounded within restrictive constitutional rights and labor laws:

> *".....that ensure rights for men and women workers are contradicted and contravened by family laws that place a woman under the guardianship of a male and require her to obtain the permission of father, husband, or other male guardian to marry, seek employment, start a business, or travel."*

In terms of recourse for discrimination, in the United States alone, a staggering 50% of women in STEM fields report having experienced sexual harassment, in contrast to 19% of their male counterparts[28] (Figure 2). Consistent with global trends for all aspects of gender discrimination, the concentration is augmented by ethnicity and melanin content of skin (highest for Black women) and geographic zone (< GS). And many abuses are not reported or pursued because women everywhere are not believed and for fear of—and experience with—retaliation[29].

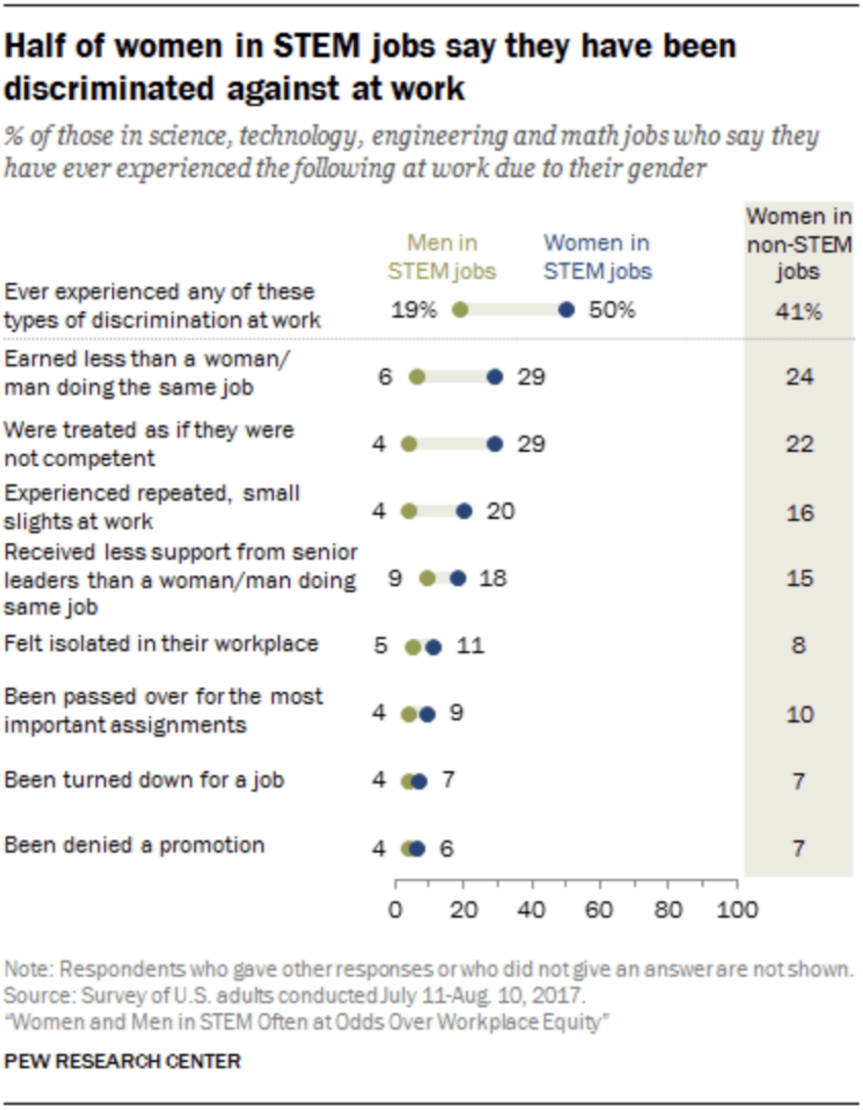

Figure 2. Fry et al.,[28] graphic on the representation of discrimination in STEM fields, PEW Research Center. Full citation in the References.

While fraudulent misrepresentation can lead to legal consequences and often results in immediate dismissal in certain sectors, plagiarism is not as readily penalized and accountability is infrequent. Lei and Zhang[30] note that incidents of plagiarism have been on the rise in recent years. In fact, the high incidence of documented plagiarism in Asia positions it as the most prevalent form of research misconduct. According to Rodrigues et al.[31], the highest rates of plagiarism are found in South, East, and Southeast Asia, as evidenced by peer-review retractions. However, this data does not account for the numerous instances where senior professors and researchers receive credit for work actually done by

their colleagues, mentees, and graduate students[32]. Given the gender statistics across the board, it can be extrapolated that women are more frequently victims of plagiarism due to their vulnerable social standing, high plagiarism rates, and bias-induced marginalization in their professions (also refer to the discussion on the "Matilda Effect" in the next section that provides additional support). Further, based on global discrimination trends, it is a reasonable assumption that women in the GS experience plagiarism at a higher rate compared to their counterparts in the GN. However, acquiring specific statistics on these matters is challenging[33]. The frequent lack of accountability after reporting such acts compounds the problem[34]. Often, the justification for these acts is directly linked to gender bias[35], further highlighting the systemic issues at play. The rest of the chapter discusses how various of these systemic biases impact women's progress in STEM in the context of academia and industry.

3. Entangled in Academia

No access, no progress

The challenges for women in academia manifest at a young age and at a significant point in development: primary and secondary education. This obstruction of intellectual development is a result of both benevolent sexism—with elements of protective paternalism and complementary gender differentiation—and hostile sexism characterized by gender antipathy evidenced in the mistreatment of girls and women[36]. Generally more prominent in the GS, particularly in countries with conservative traditionalist values, girls face significant barriers to accessing even basic education (Figure 3), which precludes their advancement to STEM studies at any level.

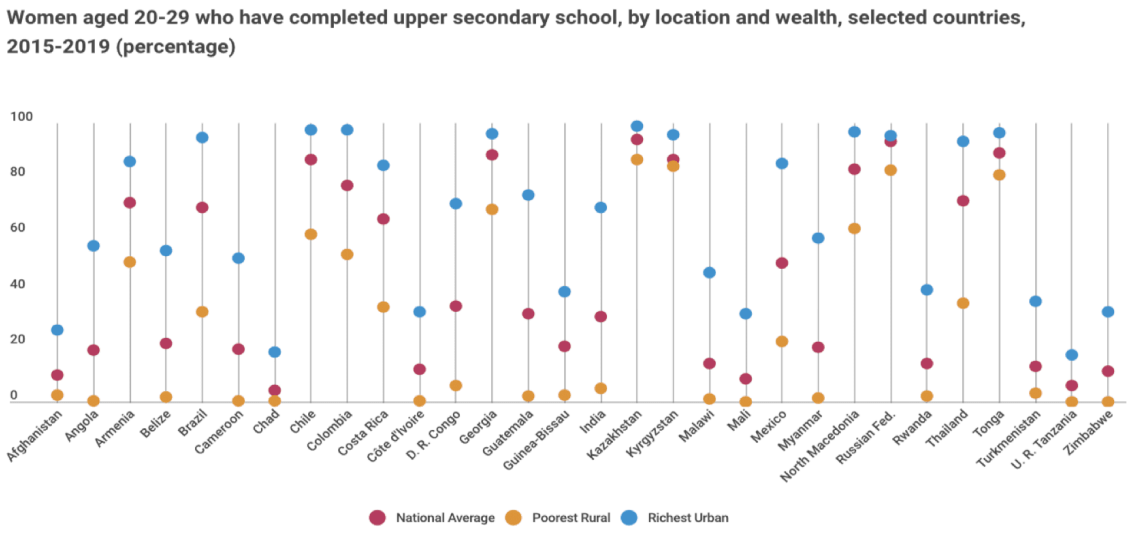

Figure 3. Graph of women's completion of upper secondary school by location, wealth, and selected countries taken from the UN Women programme report for 2022.

The prevalence of child marriage and early pregnancy are significant aspects of these barriers[37]. These barriers range from difficulties in rural transportation and the limited availability of scholarships to the high cost of education and inadequate support from government authorities. In this context, societal biases that prioritize the education of boys, enable sexual harassment, and the belief that girls are less intelligent are prevalent.

As a result, women are predominantly relegated to reproductive roles, restricting access to education for girls and subsequently for women[38][39]. For example, in the wider subcontinent of Asia, there is a longstanding tradition of not sending girls to school—a practice that reflects deep-rooted cultural norms. These barriers are rooted in a diverse range of factors, including religious and traditional beliefs, the impact of colonialism, poverty, insecurity, ethnic customs, and geographical challenges[11]. Additional problems such as the lack of quality services and government corruption, deeply intertwined with both benevolent and hostile sexism, further compound these issues. Nurullah and Naik[39] succinctly capture this reality, stating, *"Native custom excludes females from the advantage of education. Schools, strictly speaking, are confined to the education of boys. Female education was practically nonexistent."* Even after more than 70 years, Sivakumar & Manimekalai[38] affirm the persistence of these issues in their research.

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A significant barrier to girls' education is limited financial resources (Zuccala & Derrick, 2022). In numerous cultures, particularly in families struggling financially, there is a tendency to prioritize boys' education over girls'[40]. This often stems from the perception of girls as future members of another household, with their roles predominantly centered around reproduction and domestic responsibilities. As a result, investing in girls' education is seen as less advantageous for the family. The prevailing gender bias and societal norms suggest that boys are more likely to become the main financial supporters of the family. The societal preference for male education—fueled by misconceptions about the value of educating girls and the presumed intellectual superiority of boys—narrows the career prospects for females and inhibits their aspirations for higher achievements. This in turn perpetuates a vicious feedback loop, further entrenching gender disparities.

According to Ugwu et al.[20], in Africa these dynamics partially account for the population of male graduates (68.9%) being more than twice that of their female counterparts (31%). Early marriages further compound education access here too, curtailing girls' educational pursuits prematurely. According to a UNICEF[37] report, the number of child marriages has decreased from 1 in 4 a decade ago to 1 in 5 today; however, with climate change and the COVID-19 pandemic, many families are pushing girls to marry to secure financial stability. Of the estimated 650 million women who were forced into child marriages, the highest concentration is found in the Global South (GS). Notably, nearly half of these child brides, approximately 45%, are in South Asia. Following this, the East Asian Pacific region accounts for 15%, Sub-Saharan Africa for 20%, and Latin America for 9%.

Additionally, Ugwu et al.[20] observed that in the Middle East, girls' access to education remains significantly limited. It is often women and girls in rural areas who face the highest risk of oppression, a trend consistent globally among impoverished, peripheral zones (UN, 2022). Haghighat[41] attributes this to conservative Islam in the Middle East, where the religion is sometimes used as a patriarchal tool to justify the systemic hindrance of progress for girls and women. Thankfully, there has been some progress, according to the UNICEF[37] report, albeit geographically uneven and torpid on average. The United Nations' 4th resolution on childhood, early, and forced marriage (CEFM) aims to address this critical issue. Although it has not fully resolved the problem in Pakistan, initiatives that enable girls to attend school through cash assistance have shown promising results. These programs have reduced child marriage rates by 3.5% and increased the rate of girls completing secondary education by 1.9%, among other positive outcomes[42]. However, these improvements are still modest in the initial stages of

implementation. It will be crucial to monitor the impact of the consistent application of these measures over time.

In contrast, UNESCO[43] reports an encouraging change: Middle Eastern women are defying the global trend in STEM fields (Figures 4a and 4b). This contrast points to a complex and nuanced landscape of gender equality and development priorities in the region. This presents an interesting paradox in Muslim-majority nations, often characterized by conservative gender norms.

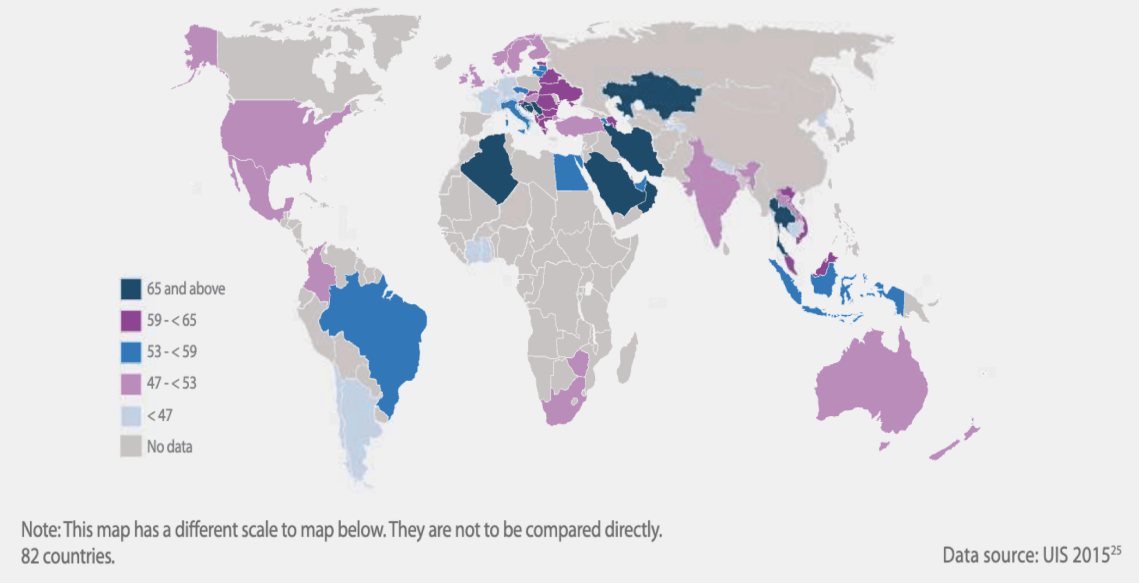

Figure 4a. Map of the percentage of female students enrolled in natural science, statistics, and mathematics programs in higher education around the world. Taken directly from the UNESCO Education 2030 report published in 2017. Full citation in References.

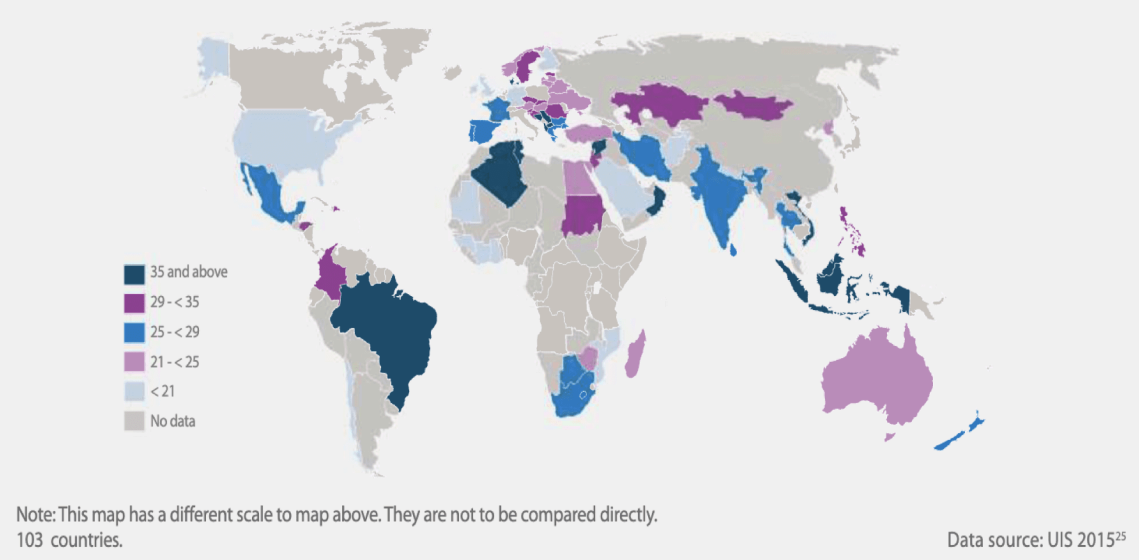

Figure 4b. Map of the percentage of female students enrolled in engineering, manufacturing, and construction programs in higher education around the world. Taken directly from the UNESCO Education 2030 report published in 2017. Full citation in References.

Syed and Kreide[14] also highlight that girls and women in urban areas in these regions see STEM as a pathway to social mobility and autonomy. With access to STEM education, girls are outperforming their male peers in mathematics and science at the primary and secondary levels. There are a number of hypotheses for this dynamic, most of which center around societal incentives. According to Syed and Kreide[14], this trend could be linked to the lessened reliance on education for social mobility among boys, as per societal norms, leading to their reduced investment in academic endeavors. However, there is evidence that any gender disparity in education ultimately impedes broader societal development[44]. Likewise, there is compelling evidence suggesting that gender equality, especially in education, significantly enhances the quality of life—not only in the economic sector but also in other developmental areas. This is supported by research from Klasen[45] and de Haan et al.[46], who both emphasize the far-reaching societal benefits of educational parity among genders.

The UNESCO[43] report on women in STEM addresses the gender gap by looking at global data. It is, however, important to note that the reliability of such research is affected by the accuracy of each country's reporting, which varies. It is also important to note that the GN data skews the global averages, so it is important to consider regional data where possible. According to this report, women are underrepresented in STEM fields globally, where female researchers constitute only 29.3% of the global

total. Additionally, women make up 35% of STEM students in higher education. In Latin America and the Caribbean, women account for less than 30% of researchers in STEM fields[47]. Country-specific data highlights this disparity: Argentina shows only 34% of women in senior STEM positions, Chile 25%, Brazil 30%, and Mexico 38%. These figures underscore the significant gender imbalance in STEM fields, especially at more advanced levels and in more advanced positions.

There has been some progress here, as in the Middle East. According to the World Economic Forum[48], the women of Latin America are attending school and graduating in higher numbers than the men. According to the UNESCO[43] report, Latin America and the Caribbean are closest to achieving gender parity. However, this trend does not fully extend to rural girls and women, who continue to face significant barriers to access in these areas in Latin America, the Caribbean, and globally. Troublingly, the report also notes that despite educational advancements, women remain underrepresented in professional sectors. This indicates that higher education levels do not necessarily translate into improved employment prospects for women. This arbitrary obstruction to both intellectual and professional development leaves us with a limited pool of female academicians and researchers.

The GN, while referred to as "developed," is rife with complications resulting from gender inequalities in STEM fields. The European Union (EU), despite being perceived as progressive, is currently facing a significant shortage of women in STEM[49]. This is particularly noteworthy considering that women constitute 52% of the European population and 57.7% of tertiary education graduates in the EU. While women are the majority among higher education graduates, their presence in the STEM workforce is disproportionately low, at less than 39% of scientists and engineers. It should be mentioned that this underrepresentation does vary significantly across EU countries. The EU Commission's 'She Figures Report'[49] further highlights this disparity in academia, revealing that women hold only 17.9% of full professorship roles in engineering and technology. The statistics expose the persistent gender gap, particularly in higher-ranking positions. Additionally, between 2015 and 2018, women were responsible for just 10.7% of patent applications, indicating their significant underrepresentation in STEM leadership and innovation sectors.

In the United States, women are also vastly underrepresented in STEM, making up just 28% of the STEM workforce, according to the 2021 US employment census. Women constituted 30% of full-time faculty in degree-granting colleges and universities. However, their presence in STEM fields was considerably lower: 22% in computer and information sciences, 19% in mathematics, 18% in physical sciences, and only 12% in engineering. Even in life sciences, a field with relatively higher female participation, women

comprised only 34% of the faculty. Tenure status and rank also reflect these disparities with a persistent, long-term trend, especially in STEM fields at four-year colleges and universities[50][51]. Women are more commonly found in part-time, junior, or lower faculty ranks and are far less represented in senior or higher ranks[52]. In a specific example of limiting gender bias in academia, McNell et al.[53] demonstrated that even student evaluations are affected. In this double-blind study, female instructors were presented as male and vice versa in online courses, after initial evaluations were made under their true gender identities. The results were striking: instructors perceived as male received evaluations that were, on average, a point higher than those disclosed as "female," regardless of performance. This has unfortunate consequences for women seeking tenure since student evaluations are a factor in tenure decisions in spite of their clearly biased nature[54]. In a similar study by Knobloch-Westerwick et al.,[55] 243 scholars were asked to rate abstracts where the author names were written gender-neutrally (first initial and last name only) and the genders were reported as reversed. The results again showed that work by authors indicated as male (but who were actually female) was favored in collaboration interest and ascribed quality, and work believed to be by females was considered of lower quality and interest. This provides a partial explanation for women's presence in research.

Making it through the gate

The data show that women are underrepresented in research roles[56][57]. This underrepresentation contributes to a disparity in publishing rates, with women still publishing at a lower rate than their male counterparts[58][59]. Additionally, women are less likely to receive authorship credit and face a more stringent peer review process[18]. Furthermore, studies have shown that manuscripts where women are listed as first or last authors are cited less frequently[6]. A factor in publishing may be the high presence of women in junior and part-time positions. Junior positions are typically heavy in teaching responsibilities and offer limited support for research, while part-time positions offer none. This underrepresentation is further exacerbated by discrimination in grant funding. Witteman et al.[60] showed that women are passed over for men for grants and scholarships specifically due to their gender. This limitation on productivity and growth potential is a significant leverage point. Due to reduced productivity, these additional societal pressures make it more difficult for women in academia to achieve recognition and perpetuate the cycle in which women academics stagnate. Additionally, they often see their best option as focusing on roles such as teaching or mentoring more than on research[61] (Fox, 1991), perpetuating the privation of social capital and low morale, resulting in an exodus of women from academia[62].

As has been the coherent theme, the paradigm of women as obligate domestic help rears its head here as well. The societal expectation that women must assume the primary role of caregiver and the subsequent cost was described by sociologists Budig and England (2001) as "The Wage Penalty for Motherhood." Women who become mothers still face workplace disadvantages compared to their childless peers[63] (Figure 5), such as lower pay and inflexible schedules, forcing them to choose between caregiving and meeting excessive work demands. Additionally, the 'motherhood penalty' often starts even before women have children, with the prescriptive assumption that all women will become mothers. Such persistent contradictions, carried with prescriptive gender bias, show up as tension between what women want to do and what they are expected to do–both coming with inherent credibility issues by virtue of our biological role. The idea of the "Maternal Wall" exemplifies this contradiction. The phrase "Maternal Wall" was coined by Joan C. Williams[64] who wrote, *"...women who have been very successful suddenly find their proficiency questioned once they become pregnant, take maternity leave, or adopt flexible work schedules. Their performance evaluations may plummet, and their political support evaporates..."* She brings attention to a troubling trend indicative of the impossible balance between what women are expected to do and able to do while shouldering the lioness's share of responsibility in both professional and personal areas of life. Moreover, highly successful women often face a greater burden of skepticism about their competence upon entering motherhood or needing flexible working arrangements as a result of this biological imperative. This shift in professional perception and treatment highlights a pervasive issue across many sectors, where women's abilities are unjustly questioned or devalued due to their prescriptive maternal responsibilities and even the very potential for such roles[65].

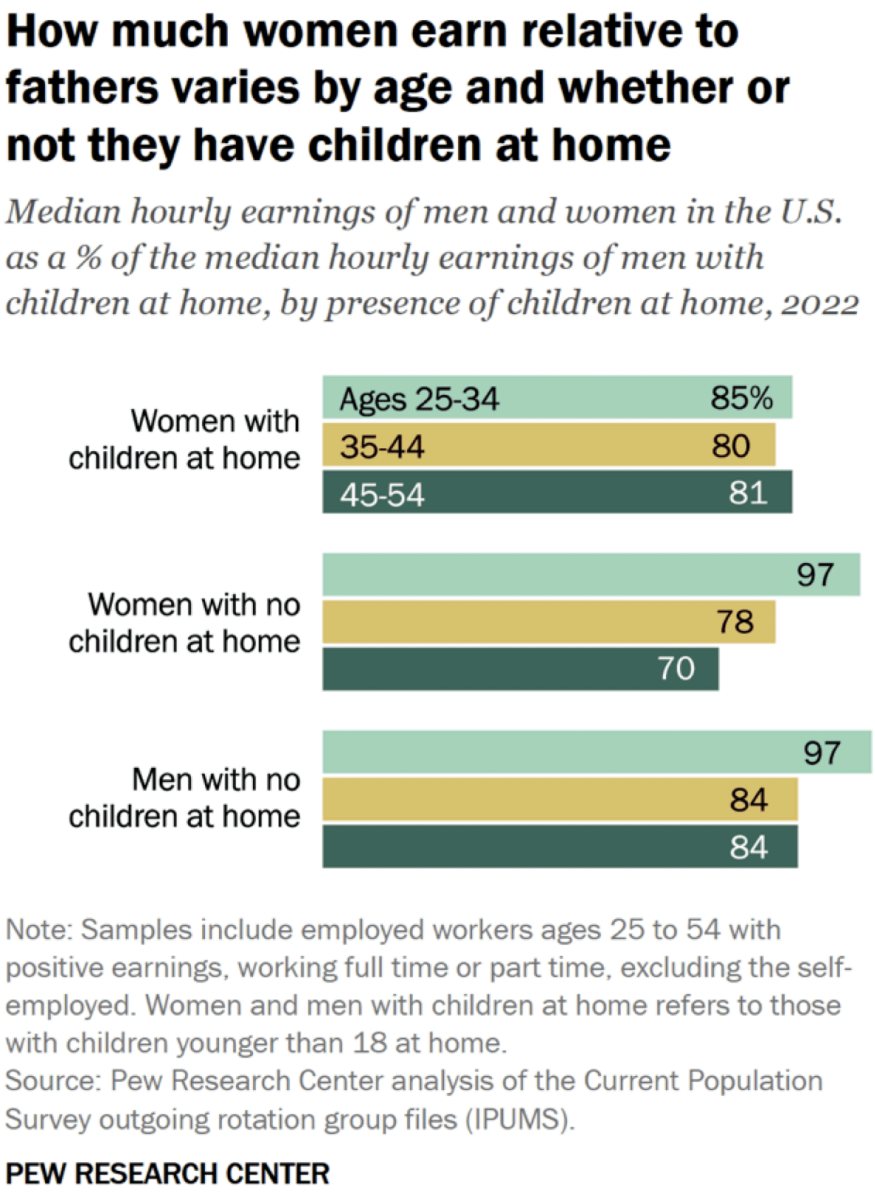

Figure 5. Kochhar (2023)[63] graphic from the PEW Research Center on the actual numbers that support the concept of the Motherhood Tax.

Because of these conflicting expectations, it is women who most often face the critical dilemma (and full mental load) of counterbalancing family responsibilities with professional goals. This challenge is notable in academia, where women must navigate the dual pressures of career advancement and family with obligate domestic responsibilities, where neither has well-defined boundaries[66] (Fox, 2005). These vicious feedback loops have far-reaching impacts, affecting career growth that additionally hinders

family involvement for both genders, a topic beyond the breadth of this chapter but with significant societal implications. This self-perpetuating feedback loop also results in the exclusion of many women from the talent pool. Additionally, as we have discussed, women must contend with limited access to necessary resources[67][68], a limitation that not only hinders their progress but also the advancement of science in general. This scarcity and hoarding of resources exacerbate the difficulties faced by women in academic STEM fields, leading to a significant reduction in their professional potential and contributions[69]. Consequently, their performance evaluations and workplace support can drastically decline, reinforcing prescriptive gender biases in academia and beyond. Reckdenwald[70] describes this as the “Perpetual loop of the patriarchy” and “Motherhood penalty.” She deftly illustrates the feedback loop detailing the immediate limitations women face upon entering the workforce and how they are subverted by the prioritizing of men for permanent positions and promotions. Women, unable to meet excessive productivity demands, must either accept lower pay and positions or “opt out” to focus solely on obligate domestic responsibilities. This self-reinforcing feedback loop is relevant across all professional sectors[63] (Figures 5 and 6).

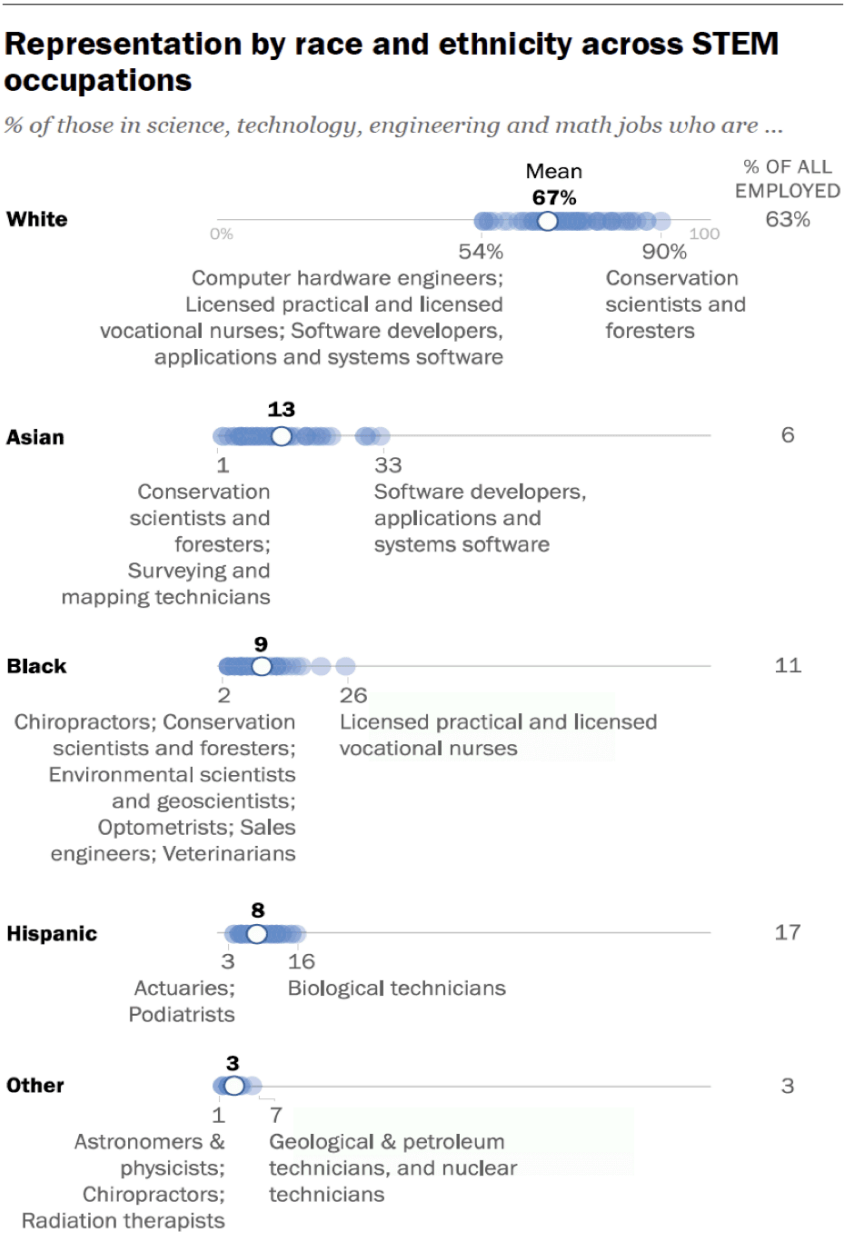

Figure 6. Earnings across racial and ethnic groups showing women in STEM make less than their male counterparts and even less by gender and ethnicity, taken directly from Fry et al.,[28] with the PEW Research Center. Full citation in the References.

Across the world, the pattern is such that the higher the academic rank, the fewer the number of women represented, with few reaching senior and leadership roles in higher education at all[71]. This trend persists despite a growing awareness of gender inequity in the academic world[72]. Furthermore, the generally low representation of women, especially in top-tier academic positions, is partially due to the exploitative tendencies of the academic labor market[73]. This exploitation is particularly harsh for young women and recent graduates who have limited experience. They are frequently expected to provide skilled labor for little or no compensation. This scenario effectively entraps them in a cycle of unpaid work, undertaken in the hope of securing a competitive advantage that never really comes for most. These young women face financial hardships and prolonged periods of isolation, driven by the distant promise of future opportunities for stability and access[74][75]. This situation both represents and exacerbates existing gender imbalances in academia as it can result in the loss of women in STEM.

Likewise, studies like that by Zheng et al.[76] have shown that women in academia face increased stress levels due to the dual burden of academic and domestic obligations, frequently with inadequate support from partners and workplaces. This issue is particularly pronounced for women in faculty and research positions, where the demands extend beyond teaching and publication duties. These women also have to navigate the challenges of securing grants and research funding[77], a task made more difficult by gender bias in funding opportunities[18] (also discussed in Chapters 2 & 16). Additionally, women in academia confront significant hurdles such as plagiarism[78] and the tendency for their published work to be cited less frequently than that of their male counterparts[79][80]. These factors collectively contribute to a cycle of challenges that perpetuate the underrepresentation and underappreciation of women in academic spheres, highlighting the need for systemic changes to break these vicious feedback loops and the handicap they pose.

Herculean ladders

While higher education has been known for its more progressive movements and stances, it can also be quite a hostile environment for women. Globally, the difficulties encountered by women in academia extend beyond merely achieving leadership roles or gaining recognition. Research consistently underscores the underrepresentation of women in positions of leadership, power, and decision-making across academic institutions[81]. These studies reveal a pervasive pattern where women, despite having the necessary qualifications and expertise, do not ascend in the ranks. Statistics show that women are significantly underrepresented in leadership positions in public universities in both the GN and GS. For

instance, within 27 European nations (part of the Global North), a mere 10% of universities that award PhDs have female vice-chancellors (VCs), as reported by the European Commission in 2012. In the UK, women constitute 45% of the academic workforce, yet they represent only 22% of professors and 35% occupy roles as deputy or pro-vice chancellors (PVCs). Furthermore, a mere 20% of vice-chancellor positions are held by women[82]. This data illustrates the significant gap in female representation in high-ranking academic roles. In the GS, the disparity of female representation is even more pronounced. For example, in Pakistan, only 0.04% of pro-vice chancellors (PVCs) are women, and these positions are typically held within women-only institutions[83]. Bhatti and Ali[84] also highlight a substantial absence of women in crucial academic and administrative roles in Pakistan's federal capital.

The limited presence of women in academic positions, particularly in top-tier roles, reinforces the male-dominated culture prevalent in academia[71]. Women who do attain high-ranking positions often face an even more complex set of challenges due to the intensely competitive nature of the academic environment[85]. Brabazon and Schulz[86] effectively encapsulate these difficulties, emphasizing the extra burden that leadership roles impose on women in academia. When women do attain such positions, it is often seen as a temporary arrangement, setting the platform for a male successor once specific changes have become integrated[87]. Regrettably, this scenario is a global phenomenon[86].

4. Intertwined in Industry

Convolutions & Evolutions

The low representation of women in the STEM field in industry is very much a reflection of the systemic limitations that affect access to education we have been discussing to this point. These systemic issues extend into the workplace, post-academia. We see limited numbers of women graduating from academic institutions and even fewer actually entering the workforce at the level of their qualifications. Bussey and Bandura[88] show that stereotypes not only shape how males and females are perceived, evaluated, and treated in gender-specific ways but also perpetuate behaviors that reinforce these initial stereotypes. This is still true today. Women are taken less seriously than men, even while performing as well as or outperforming them[89]. This 'subtlety' in gender-biased behaviors has some material consequences in the careers of women in industry, as in academia. West & Zimmerman[90] explain the ways in which tying gender roles to biological sex legitimizes social arrangements as natural differences[91]. For instance, when women and men perform the same task, such as supervising or advising, they are

perceived differently by both women and men [92]. In the same vein, women often face significant challenges in securing roles traditionally viewed as "male jobs," particularly in management and upper management. Typically, women receive lower salaries, wield less power, and encounter fewer opportunities compared to their male counterparts[28][93][94]. As additional reinforcement, male applicants experience bias when applying for positions that are stereotypically considered "feminine"[95] [96]. Discrimination apparently arises, in part, from “ambiguity” in the qualifications of job applicants. That is to say, when an applicant’s credentials are vague, stereotypes are used to “fill in the blanks”[6]. For instance, if a woman applies for a job as a factory manager and little information is available about her, there is a tendency to assume she lacks traditionally masculine qualities, such as assertiveness, which are often deemed necessary for success in such a role. Problematically, leadership qualities like assertiveness can be perceived as negative in women and as powerful in men[97]. Conversely, a man applying to be a nurse may be viewed as lacking “nurturing” qualities attributed to feminine stereotypes[35].

Heilmann et al.[6] further explain that prescriptive gender stereotypes contribute to gender bias through established normative behavior standards and their reinforcement. When women deviate from these standards, or are perceived to deviate, they often face social disapproval and penalties. Women must navigate not only the barriers imposed by descriptive stereotypes, which question their inherent capabilities, but also the societal consequences of contravening prescriptive stereotypes. van Veleen et al. [98] discuss how these prescriptive gender limitations result in a suppression of creativity and authenticity due to "stereotype threat." Stereotype threat refers to the fear of confirming negative stereotypes about one's prescribed group. Consequently, women often avoid fields where they are perceived as inherently less capable than men, like mathematics and science, thereby reinforcing the stereotype of female incompetence in these areas. Alternatively, women may leave these fields for occupations that are less psychologically burdensome in terms of societal norms because of these impossible hurdles and the stress associated with them[50]. This avoidance behavior is partially attributed to 'social identity threat,' which Van Veelen et al.[98] define as the experience of feeling devalued or stigmatized at work based on gender identity, similar to stereotype threat[97].

Showing up isn’t enough

The US Equal Employment Opportunity Commission[99] reported that women constitute approximately 75% of office and clerical workers in all fields. This trend, typical in many postcolonial societies globally,

is often more pronounced in the GS than in the GN because of the limitations on women's advancement. This is often due to access and barriers to progress. While more women are entering STEM employment, it bears reminding that they are frequently relegated to positions below their academic credentials. Prior to the COVID-19 pandemic, STEM employment growth (9.2%) was predicted to surpass overall economy-wide employment growth (3.7%) from 2019 to 2029[28]. The analysis also indicates that average earnings in STEM are significantly higher than in other sectors. Despite this, as in other sectors, there is a noticeable pay gap between women and men in STEM, with additional disparities among different racial and ethnic groups. The analysis further shows that Asian men in STEM occupations have the highest average earnings, while Black and Hispanic women have the lowest in most areas of STEM. Despite accounting for factors such as education and job characteristics, gender presence and ethnic pay gaps remain persistent, as highlighted throughout this literature review[28] (Figures 6 & 7). The pay gap is a quantitative example of devaluation and both corroborates and perpetuates the cycle of gender bias. These stereotypes have established normative standards for behavior, leading to disapproval and social penalties when they are directly 'violated' through qualities like assertiveness[6].

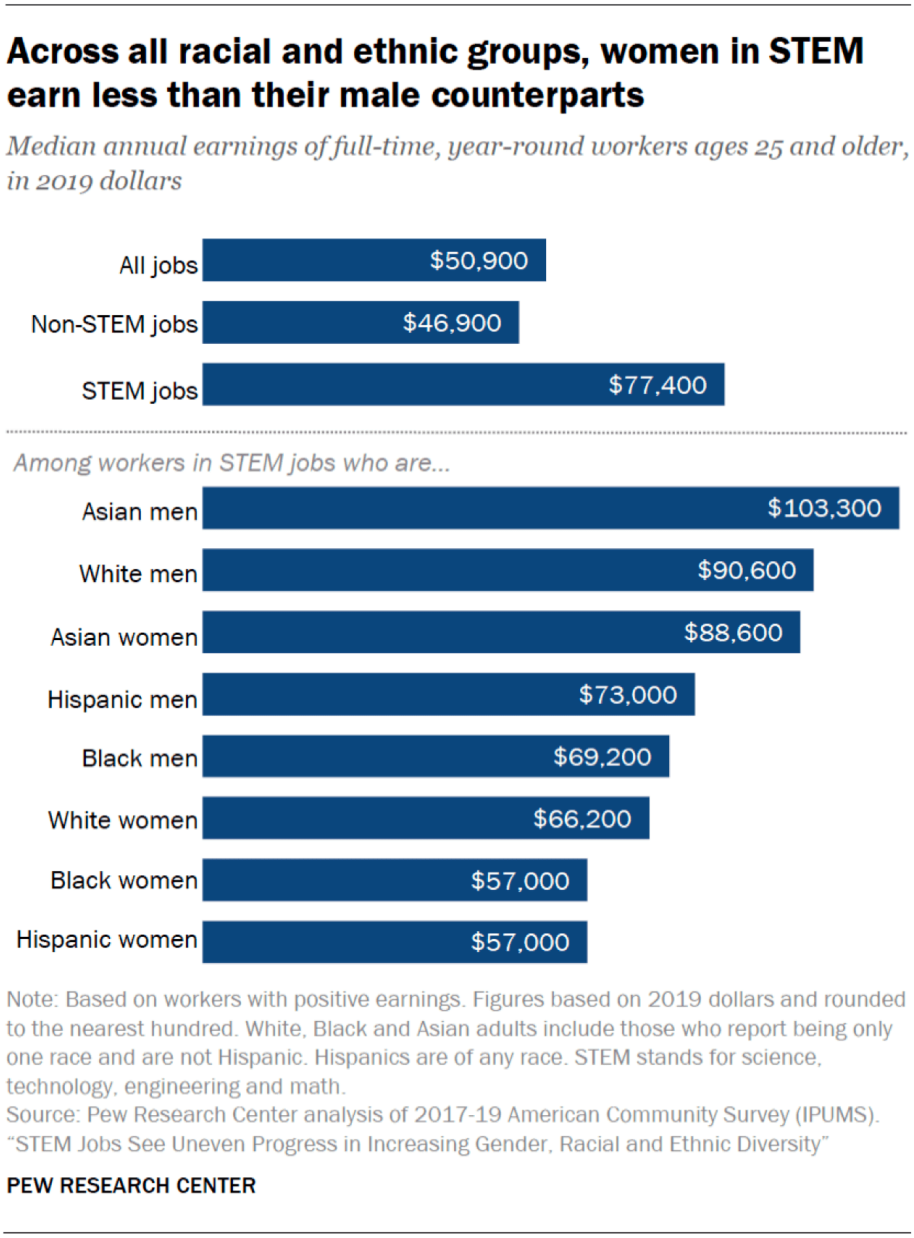

Figure 7. Representations of ethnicity across STEM occupations as presented in the Fry et al.[28] report through the PEW Research Center. Full citation can be found in the References.

This deep-rooted gender bias inevitably leads to power imbalances in everyday workplace interactions, and this power is portrayed, exhibited, and enabled in emails, meetings, and conversations. Such dynamics reinforce the notion that success is typically associated with being male. Consequently, women who aspire to advance professionally often adopt behaviors similar to their male colleagues or utilize

prescriptive gender stereotypes to their benefit[34]. On the other hand, certain professional expectations are tied to a specific concept of disciplined and embodied femininity. This presents women with a dilemma: they can either adopt traits of hegemonic masculinity, potentially facing backlash, or align with what Hamilton et al.[34] term the “hegemonic femininity incentive.” This phrase refers to the relative advantages that come with adhering to traditional feminine behaviors in workplace cultures where masculine traits are not rewarded in women. They assert that by upholding these societal norms rather than challenging gender-based oppression, women perpetuate inequality in their pursuit of a place within the professional hierarchy. However, this can also undermine their ambitions by keeping them in limited positions because they lack “leadership skills” attributed to male traits. To gain respect, power, and privilege, women often find themselves having to “play a game on top of a game,” demonstrating an understanding of, and an ability to navigate, the complex dynamics of their organizational environment around these gender expectations[34].

Beyond navigating impossible workplace politics, women are often required to exceed the baseline performance standards deemed sufficient for their male colleagues' advancement. Research indicates that women are held to stricter performance criteria, necessitating that they work harder to achieve similar recognition[58][100]. Consequently, women are less likely to ascend to high-status, high-paying positions, such as those at the management level. Furthermore, the performance benchmarks set for women are arbitrarily higher, making them increasingly unattainable and serving as a normalized barrier to their professional progression[35]. This trend results in women generally occupying lower socioeconomic statuses compared to their male counterparts throughout their careers (Haines et al., 2019).

Misfits and the ‘Old Boys’ Club’

In this vein, it is clear that prescriptive gender stereotypes play a significant role in promoting gender bias as well as in their application. As we discussed in the previous subsection, violating these normative expectations comes with consequences. Additionally, the higher the position a woman holds, the more likely it is that the penalties for violating these stereotypes will be harsher and more pronounced[101]. Thus, women are judged more harshly, penalized more harshly, and demoted more frequently. Additionally, the success of women can be weaponized[102]. This comes in the form of the phenomenon known as the "glass cliff," which affects women who attain high-level leadership positions. This concept refers to the tendency for women to be more likely to be promoted to positions of organizational

leadership in times of crisis, while men are more likely to achieve such positions in prosperous times. This situation represents a form of professional duplicity where women are often set up for failure, reinforcing gender stereotypes and relieving male counterparts from scrutiny, particularly when change is needed. This also provides a control for how far and how long a woman can attain leadership. This gatekeeping is often referred to as the “old boys’ club” or “the boys’ club.”

The influence of the 'old boys' club' network is often evident, where men's chances of promotion are perceived to increase through shared interests and activities, while women may find themselves relegated to the status of 'outsiders' in a system that predominantly accommodates men[103][35]. This dynamic is noticeable across various entry points into STEM trajectories. For instance, recruitment and hiring practices play a significant role in disadvantaging women[104]. Informal recruitment methods, such as referrals through existing networks, tend to result in a higher proportion of male hires. In contrast, open recruitment approaches, such as utilizing employment agencies or job advertisements, can reduce gender bias in hiring, especially when job applicants' names are gender-neutral[105].

Uhlmann and Cohen[35] uncovered a troubling form of discrimination related to the redefinition of merit criteria for applicants belonging to favored groups. This meant that not only were job requirements adjusted to align with traditionally male perspectives, but they were also modified based on gender. In their experiments, this occurred in two distinct ways. Firstly, candidate evaluators tailored their criteria to favor the qualities that individual applicants of the desired gender happened to possess. For example, they observed a double standard in which women candidates with children were viewed as having lowered credibility and fitness, while identifying as family-oriented redefined this quality as more important and engendered trust when possessed by male applicants. Secondly, when men did not commit to specific hiring criteria, implicit bias played a decisive role in favoring male applicants, whereas decisions were more equitable when criteria were pre-established with the same men[106].

To further exacerbate the systemic inequities, prescriptive gender stereotypes often manifest in daily microaggressions that leave women with the psychological challenges of ‘not fitting in’ and ‘not belonging,’ which have led women to leave STEM fields[50]. These inequities can manifest as being overlooked for tasks that build skill sets and desired experience or being given low levels of responsibility to reinforce the woman’s lack of utility. This kind of dismissiveness and devaluing of women’s positions and capacities shows up pervasively as women in positions of management or authority are subjugated to

male colleagues in insidious ways– like being asked to get coffee for male counterparts, while business is discussed with the women's male assistants in their absence[107].

This segues into another challenge women in STEM face in terms of a lack of respect from peers and supervisors, as we noted in academia. Simply because of prescriptive gender bias, women are seen as less qualified and treated as outsiders. Working in the STEM industry has historically been seen as inherently masculine (i.e., not feminine or meant for women). Ettinger *et al*.[108] discuss that women were often reminded that being a woman was seemingly at odds with being an engineer, and they received mixed messages about how they should look and act, forcing a precarious tightrope walk between hegemonic masculinity expectations and demonstrating an acceptable level of hegemonic femininity. Consistent with the literature (and the experience of many of us), this is concordant in all STEM fields and a result of the incursion of pervasive prescriptive gender stereotypes. Women who achieve success in male-dominated jobs often face harassment, isolation, hostility, and increased stress due to being perceived as 'tokens'. Their presence may be seen as a means to fulfill gender equity rules and quotas, a dynamic decades old[109][110][111], undermining women's talents and contributions. Because of the inconsistency in women's presence in STEM fields, the idiosyncrasies (Figure 8) may be indicative of varying levels of intensity in the manifestation of these biases.

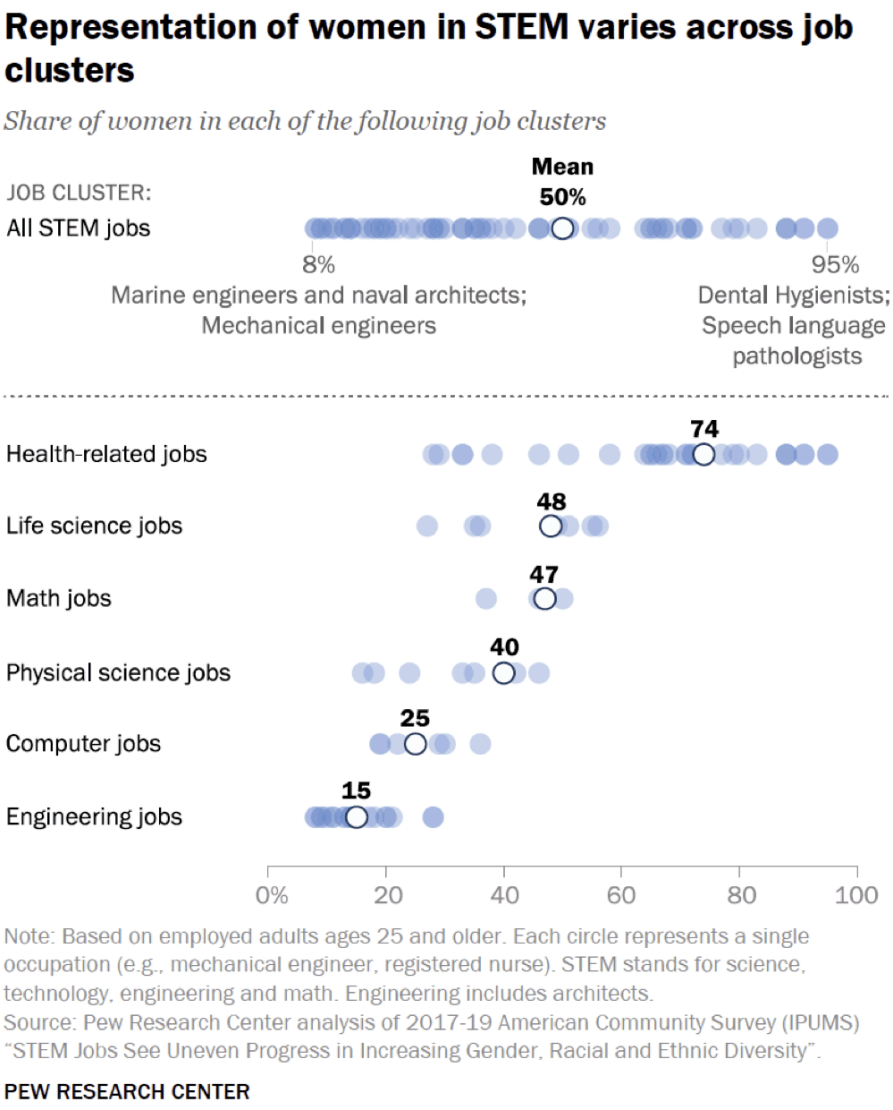

Figure 8. Fry et al.,[28] PEW Research Center report on the presence of women in different STEM sectors. Full citation in the References.

These stereotypes have established normative standards for behavior, leading to disapproval and social penalties when they are directly 'violated', as in the case of women's advancement or assertiveness[6]. The normative pressures described above lead to psychological challenges for women in STEM[104]. Additionally, individual personality traits have been identified as a career barrier for women[112]. This can manifest as a 'social identity threat,' as discussed earlier[97][98], where the fear of being authentic results in self-limitation. Research indicates that women often respond to negative feedback by internalizing doubts about their abilities[113]. For example, when confronted with comments like Lawrence Summers'

(American Economist and Secretary of the Treasury, 1999–2001) suggesting that women may be ill-suited for high-power, high-intensity, high-end jobs in science/engineering, many young women find these remarks offensive. However, instead of interpreting these derogatory comments as a call to confrontation, they instead strive to overachieve further, individually and independently[114]. The Impostor Phenomenon (IP) has been utilized by various authors to elucidate the inner turmoil that women often grapple with because of these incongruities[115][116]. This phenomenon stems from external societal narratives that lead women to question their own success and view themselves as 'impostors'. The impostor phenomenon (or impostor syndrome) encompasses the internal sense that an individual harbors, where they believe they are not genuinely deserving of their accomplishments, even when they have achieved high levels of success and possess clear indicators of competence. This inability to acknowledge their achievements fully results in many individuals, including women affected by it, attributing their success to factors such as luck, working exceptionally hard, or even manipulation[117].

All of the statistics cited in the chapter support the grave impact of these dynamics, as they clearly demonstrate women persisting in lower numbers in fields dominated by male privilege, earning lower wages for the same work, and battling the same systemic barriers as we have throughout history. The UNESCO[43] statistics also reinforce the intensified effects of these dynamics in the GS, where there is less societal pressure or framework for equality. In line with this, Elacqua et al.[118] suggest that the glass ceiling, where access appears open but these systemic norms and perceptions limit women's growth, is likely to be perpetuated in cultures that enable differential views of and treatment of men vs. women. These dynamics are global–active in the GN and operating with much greater intensity in the GS. This would also apply to the glass ceiling and glass cliff.

Trapped in 2G: Glass Ceiling, Glass Cliff

Looking at the extensive works on the subject in all sectors, it becomes evident that there is a social process and hierarchy maintained and preserved that privileges certain men with male-typed behaviors and characteristics—referred to as hegemonic masculinity and the Old Boys' Club. Grounded in both benevolent and hostile sexism that underlies prescriptive gender stereotypes, this social construct has a detrimental effect on the authentic expression of femininity and feminine behaviors and attributes in women. Despite the achievements of a few women who have managed to break through this barrier, some posthumously, it remains a pervasive and limiting force that hinders the progress of many women in various fields. The phrase "glass ceiling," coined by Marilyn Loden (1978), is commonly used to

describe the difficulties faced by women and other marginalized identities when endeavoring to move to higher roles in a male-dominated hierarchy. The barriers are often ‘informal’, meaning that in the absence of specifically defined policies we are more likely to be restricted from advancing through accepted norms and implicit biases[119][120]. Thus, the concept of the glass ceiling serves as a well-known metaphor to illustrate the phenomenon where many women find themselves unable to progress beyond a certain point in their careers, irrespective of their accomplishments or qualifications[25]. This distinctive form of inequality has been observed in the majority of workplace settings[6]. It is also intensified for women of color[121].

The “glass” is being able to see the benefits of advancement and participating in the professions and trajectories that should lead women to the top but never quite attaining the same regardless of contribution. As the statistics have demonstrated, even as women wrangle higher-level positions, a significant income disparity persists, and this gap widens as women progress up the organizational hierarchy[63] maintaining the delineation in success. This gender pay gap endures, even when factors such as the quality of the educational institution attended, academic achievements, specialization, job type, organization type, labor supply, current working hours, and family situations are taken into consideration. Furthermore, Kochhar[63] highlighted that the gender pay gap tends to increase with age and ethnicity, with an additional gap among Black women.

Additionally, women as a group consistently receive less recognition than their male counterparts for innovations, discoveries, and contributions, as noted by Sieghart in 2021. This phenomenon is unsurprising when we consider the historical oppression of women with alternative perspectives, many of whom were forcibly institutionalized in the 19th century[122]. In the realm of STEM, there exists a phenomenon known as *"The Matilda Effect,"* which pertains to the tendency to overlook or downplay the contributions of women in the field[123]. While we often hear about exceptional cases of women breaking through the "glass ceiling" in STEM and paving the way for others, these women are sometimes portrayed as outliers. However, when we examine the Matilda Effect, we encounter an intriguing contrast and contradiction to the notion of exceptional women as anomalies. Two notable examples are Mileva Marić (Einstein's first wife) and Marie Curie, who needs no introduction. Mileva Marić received limited recognition for her contributions, while Marie Curie not only received credit for her collaborative work with her husband but also secured a lasting place in history for her discoveries. What made the difference? It often boils down to the willingness of their respective husbands to give them due credit for their contributions.

It's important to acknowledge that there are likely numerous other women whose achievements have been overshadowed or buried by their male counterparts[124][125][126]. Because of the omission of such women, it is difficult to know how many discoveries should be attributed to women, nor how many have been lost as a result of gender dismissiveness[21][127][4]. Some, like Theano of Crotone, go back as far as the 6th century BCE. She is an outstanding example due to the fame of her male counterparts and is likely at the very least a credit-worthy contributor to Pythagoras—and she was not an anomaly[128]. Additional modern examples of the poaching of intellectual property from women in STEM resulting in renown for the men who took credit:

Nettie Stevens (1905) was an American geneticist who discovered sex chromosomes. She made significant contributions to our understanding of XY sex determinism, a fundamental concept in genetics. Edmund Wilson is given credit for the discovery[129].

Alice Ball (1915) was an African American chemist who developed a treatment for leprosy, a significant medical breakthrough. Her work involved the development of an injectable oil extract of chaulmoogra oil that could be used to treat leprosy and was referred to as the “Ball method.” Her work was published by Arthur Dean in 1920 with no mention of her but was officially recognized in 2000[130].

Marietta Blau (1937) was an Austrian physicist who made significant contributions to the field of particle physics. She is best known for her invention of the photographic technique known as the “Blau method,” which was used to study cosmic radiation. Cecil Powell won the Nobel Prize in 1950, taking credit for her work[131].

Lise Meitner (1938) was an Austrian physicist who worked directly with the chemists Otto Hahn and Fritz Strassmann in research that led to the discovery of uranium fission. Otto Hahn won the Nobel Prize for it. Her groundbreaking work included the discovery of protactinium and her pivotal role in the discovery of nuclear fission[131].

Rosalind Franklin (1953) was an English chemist and X-ray crystallographer who played a crucial role in elucidating the structure of DNA. Her work was instrumental in the discovery of the double helix structure of DNA, although she was overlooked for the Nobel Prize in favor of Watson and Crick, who took full credit[132].

Chien-Shiung Wu (1956) was a Chinese-American physicist who made significant contributions to the field of particle physics. She is best known for her work on the Wu experiment, which demonstrated that parity is not conserved in weak interactions. Lee and Yang, whose work Wu advanced theoretically and

experientially, received the Nobel Prize for the discovery in 1957 while Wu was not mentioned[133]. She became an outspoken advocate about sexism in science.

Rachel Carson (1962) was an American zoologist and writer. She was the first woman to take the Civil Service test and worked for the U.S. Fish and Wildlife Service. She ultimately wrote the famous work “Silent Spring” in an appeal to stop the use of damaging and dangerous pesticides due to their long-term effects on birds, pollinators, and humans. As a result of this work, she was barraged with prescriptive gender stereotypes publicly for years after the publication in an effort to silence her and undermine the credibility of her work[134]. Silent Spring is still one of the most influential works to date for the environmental movement.

Jocelyn Bell Burnell (1967) is a Northern Irish astrophysicist who made the groundbreaking discovery of the first radio pulsars. Her discovery was one of the most significant astronomical discoveries of the 20th century[135].

Jean Purdy (1978) was a British embryologist and nurse who played a key role in the birth of the first IVF baby. However, she was excluded from a plaque at the Oldham hospitals involved, and the two men credited with the discovery never mentioned her contribution[136].

Gladys West (~1986) was an African American mathematician who worked for the U.S. Navy. Her work involved developing algorithms to model the shape of the Earth, laying the foundation for Geographic Information Systems[137].

These are just a small cross-section of women with high-profile contributions who have experienced the Matilda Effect. It's important to recognize that the likelihood of an intensified dynamic of disregard is even higher in the GS. The notable example from India that we mentioned briefly in the introduction is Bibha Chowdhuri, a physicist who made a groundbreaking discovery related to a new subatomic particle in 1948. She would have faced even greater limitations if not for her Brahmo status, which allowed her some societal privileges like access to education. She was one of three women to receive a postgraduate degree from the University of Calcutta in physics and the first woman faculty member at the Tata Institute of Fundamental Research in Mumbai (TIFR), where her contributions to building particle detectors were disregarded while her male colleagues enjoyed recognition and national awards. She was overlooked for at least one Nobel Prize, possibly two, in favor of a male colleague who took full credit for her work. These women’s stories raise the question of how many other women in STEM have had their work plagiarized. Unfortunately, due to a variety of factors such as reporting issues, lack of accountability,

and insufficient recognition in the discourse, it is currently impossible to provide an accurate answer to this question. We know, however, that purely based on gender rejection being higher for women[78], documented evidence of plagiarism and scientific publication retraction[31][138], and systemic post-colonial gender discrimination dynamics[11] we can reasonably extrapolate that plagiarism of women's work in STEM follows the same patterns. We also know that the rate of plagiarism is augmented considerably in the GS[138], making it reasonable to assume the rates of plagiarism for women are higher, as well. There is still no substantive punishment for it in most cases[139], neither in the GS nor the GN[138].

5. COVID-19 and Other Exacerbations

According to the World Economic Forum (2021), COVID-19 widened the gender gap and is projected to take 135 years to close that divide. The COVID-19 pandemic has aggravated pre-existing inequalities, leading to a range of negative consequences. According to Kuhlmann et al.[140], pandemic policies have had significant adverse effects on women's health, including constraints on prevention and support services, weakened reproductive rights, and an increase in sexual violence. Additionally, women's leadership during the pandemic was often weak, and healthcare systems struggled to protect women's health and essential public health targets. Furthermore, the pandemic has magnified the effects of existing gendered discriminatory practices in the field of medicine[141], and this issue has been a concern for some time[142]. Overall, the measures implemented in response to the pandemic have compounded the already precarious professional position of women, as discussed further, emphasizing the need to address these gender disparities and inequalities[143]. As with all of the global dynamics of marginalization and inequality, these effects are heavily intensified in the GS compared to the GN.

The COVID-19 pandemic has had a significant impact on the progress towards achieving SDG 5, the goal dedicated specifically to gender equality. In STEM, women scientists have been disproportionately affected over male counterparts—and that was most thoroughly reported in Europe and the US[144]. Women of color with children were the most impacted by COVID-19 restrictions, according to a study of over 3,000 Brazilian scientists[145]. The results of the study showed that in Brazil, light-skinned mothers and dark-skinned women (regardless of whether they are mothers) were most significantly impacted, a result echoed in North America[146]. We can extrapolate, based on global discrimination patterns, that these patterns hold elsewhere in the world, higher in intensity in the GS. Collins et al.[147] reported several high-impact factors negatively affected the productivity of women in STEM during the COVID pandemic,

including domestic and caregiving responsibilities reducing available working hours (44%), complications in collaborating with colleagues (42%), limited access to teaching faculty and/or administrative staff (30%), and changes in institutional/departmental priorities (26%). Additionally, the report highlighted other concerns, including logistic difficulties of working from home, social isolation, concern for their own health, difficulty balancing work and home life, lack of access to the outdoors/cabin fever, lack of access to basic necessities or services, increased family strain, and lack of sleep.

An additional study conducted by Staniscuaski et al.[145] also found that women reported experiencing greater restrictions on their time due to caregiving obligations compared to their male counterparts. In this study, 55% of participants were male, while 43% were women, and the majority of participants were predominantly from North America (34%), Europe (34%), and Asia (16%). The National Academy of Sciences conducted a survey of women in STEM, revealing that 90% of female faculty reported that the majority of their children's school and childcare demands fell on their shoulders, with only 9% reporting an equal sharing of domestic and caregiving duties with a spouse. Additionally, a study conducted by UNESCO in 2020 (which sampled 1,470 female researchers in developing countries within their network) showed that women in STEM faced a disproportionate risk of losing employment during the pandemic. On average, respondents indicated that the share of childcare responsibilities assigned to them had increased from 51% to 66% during the pandemic. Women also reported being responsible for 69% of homeschooling duties. The representation of male experts in the media significantly outweighed female experts, with a ratio of almost 3:1 (male to female). Furthermore, women in STEM reported that, on average, the share of household chores assigned to them had increased from 52% before the pandemic to 58% during the pandemic.

The pandemic also isolated many women in positions far from their homes and families, making it impossible for them to travel back for significantly extended periods[148]. Caldarulo et al.[149] emphasized the importance of considering how the post-pandemic shift toward hybrid work practices affects gender inequity in STEM, as it brings about increased pressures related to childcare needs and competing work and domestic demands. Notably, this category had the highest percentage of negative responses in the UNESCO[43] survey. It is crucial to recognize that there are other pandemic impacts that may not be immediately apparent. In North America, women from the most underrepresented groups in academia, such as Black, Latinx, and Native American women, are likely to experience more severe impacts due to higher death rates among these groups, as discussed by Jason et al. in[141]. In marginalized and peripheral

areas of the world, primarily in the GS, these effects were intensified, and there was an increase in violence against women, as reported by Al-Ali in[150] and Alon et al. in[146].

The gaps in STEM are further exacerbated by the issue of English as the global language of science, which poses difficulties for non-English-speaking researchers in terms of access to quality language learning and a lack of attention to translations[151][152]. This issue is further detailed in Chapter 16. If we extrapolate the patterns related to barriers in learning and access to education and academic resources[153], language becomes another area where women are likely to face restrictions. This is particularly relevant when considering access to English language learning, which shows that in mid- to low-income periphery countries, access tends to be limited to the privileged (Murray, 2020).

Finally, there is the issue of ageism. There is ample evidence that age exacerbates other biases. Rochon et al.[154] discuss various effects of ageism on women, like fewer and unequal opportunities in the workplace as they age, lack of research on topics relating to women and aging, recruitment, and pensions. According to a WHO report in 2021 on health, women receive 27% less in pension payments in the Organisation for Economic Co-operation and Development countries. There is little on the topic of ageism specifically in STEM, so a thorough exploration is not currently possible. However, as with other trends around gender bias, we can infer that it is likely that age exacerbates the effects of gender bias in STEM. There are undoubtedly many more barriers to mention, particularly regarding the gatekeeping of privilege. As demonstrated throughout this paper, women are rarely in positions of privilege, and factors such as ethnicity and skin color further intensify these disparities.

6. Concluding thoughts

After considering the literature that has been discussed in this chapter and the exigent moment in history we find ourselves in, there are several drivers that could amend society's functional apparatus– which includes government- and judicial-approved changes, the national/regional socioeconomic landscape, social globalization, and women's movements and other inclusive initiatives[12][155][16]. While progress has been made, particularly in the GS, the world is still far from gender equity. The benefits of diversity and inclusion are innumerable[153][156][89][157][158][41]. Moreover, we are at a time in history when there is a greater imperative to ensure we are taking full advantage of our social capital[159], particularly in STEM, to solve wicked problems. After noting overlapping and repetitious dynamics, there are several actions that come up recurrently that could accelerate gender equality and inclusivity in STEM fields (and

subsequent acceleration toward achieving SGD5). This list (Box 1) is far from exhaustive. There are numerous national and internationally based reports and synthesis papers that can be relied on, with just a small portion in the References. However, these are a modest and fundamental start.

- Greater attention to laws that ratify women's rights[153] including tax monies and grants toward equal access to childcare and education (also see Chapter 12);
- Bias training with implicit bias as a focus[160] starting as young as possible[161];
- Exploring normative processes in global (UN) dynamics to mitigate limiting normative behaviors[16];
- Vectors for sharing resources with other scientists[67] (Chapter 15), particularly women and those in the GS;
- More systematic monitoring and infrastructure to ensure accountability for plagiarism claims[31];
- Utilizing 'blind' hiring practices[35];
- Using experiential variables in gender research and quantitative measurement of them[36];
- Citing women in science[162];
- Increasing the diversity of scientific leadership groups (journals, editorial boards, and societies) with a focus on equal gender representation and ethnic diversity,
- lowering publishing costs, and
- disseminating more research from and about the GS[163][164].

Box 1. A call to action: acceleration towards SDG5

Finally, this chapter sheds light on the specific challenges faced by women in STEM across different regions and has highlighted the need for context-sensitive interventions. These interventions play a vital role in the shift to gender equality in these critical fields. It is evident that both the GS and GN need evolution when it comes to women's roles and challenges in STEM, both in academia as well as in the industrial sectors, in spite of decades of research and isolated successes. In essence, all of the limitations to women in STEM are indicative of the systemic, implicit gender bias underpinning much of the obstructive dynamics discussed in this chapter. All of these mechanisms that fuel the challenges faced by women in STEM serve as a stark reminder of the pervasive gender bias that results in a serious privation of social capital. Gender equality is not merely a moral imperative; it is a fundamental requirement for building a sustainable future. The feedback loops are many, and the leverage points are known. It was our

goal to provide this synthesis of challenges and solutions for women in STEM so that they can be addressed rationally and promptly.

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