Exploring the Multifaceted Challenges of Women in Engineering: A Comprehensive Literature Review

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***Abstract*—The present research delves into the complex dynamics of gender equality, highlighting women's experiences within the engineering sector. Drawing from a literature spanning from 2005 to 2023, we gathered insights from 108 pertinent articles on the topic. Our results show that a substantial portion of research underscore the persistent biases and barriers women encounter in engineering. Through our analysis, we unveiled four dominant themes: "The Impact of Sex Differences on Productivity," "Gender Digital Divide," "Discriminatory Behaviour," and "Women and Performance." Applying the glass ceiling theory as analytical framework, we discern a prevailing neglect toward women's challenges in the engineering field. Our findings accentuate the necessity for innovative policy interventions. To this end, we introduce a comprehensive policy model tailored to champion robust gender equity initiatives within the engineering field.**

***Index Terms*—Discriminatory behaviour, gender equity, gender digital divide, literature review, women in engineering.**

I. Introduction

AT THE dawn of the previous century, the United Nations (UN) proposed eight developmental goals to reach specific milestones by 2015. These objectives included promoting gender equality and empowering women. In 2015, the UN bolstered these goals with 17 sustainable development goals (SDGs) intended to be achieved by 2030 [73]. In an exceptional display of global accord, 193 UN member nations assented to the SDGs in 2015 [40]. These SDGs encompassed targets aimed at education, health, and, most pertinently to this study—gender equality. Ban Ki-moon, the UN Secretary-General at the time, defined this as a "shared vision of humanity and a social contract between the world's leaders and the people" [90]. Consequently, UN member states have implemented the 2030 Agenda by creating a transformational action plan based on these SDGs [26]. In addition, in October 2023, the discussion on gender equity in the workplace was reinvigorated when the Nobel Prize for Economics was awarded to Harvard Professor Claudia Goldin. Her influential work underscores that despite incremental gains achieved by women over the decades, genuine equality remains an elusive goal [29].

This contemporary narrative is intrinsically linked to the focus of our study: gender equality and women's empowerment, a cornerstone of the SDGs. Within the domain of gender discrimination, two predominant manifestations arise, as categorized by Baroudi and Truman [10]: "access" and "treatment." The former, "access," captures the instances where attributes unrelated to qualifications, such as gender, inadvertently dictate managerial recruitment and promotion decisions. The latter, "treatment," delves into the nuanced inequalities women face in remuneration, career advancement, and symbolic recognition, epitomized by notions like "nice girls do not get the corner office." Given this dual framework, our research delves into the issues of both access and treatment of women within the engineering sector by exploring the current available literature on the phenomenon.

The continuing challenges surrounding the access to and treatment of women in engineering pose a significant conundrum. Realizing the SDGs appears untenable without redressing these gender imbalances within the engineering domain. Indeed, gender equality is not merely a pressing concern but an imperative. It is foundational for fostering a thriving and sustainable planet and stands as an intrinsic human right [90].

There has been some progress in equal opportunity (EEO) in most Western countries where EEO laws have advanced gender equality. For instance, EEO laws in many countries state that discrimination is illegal based on specific characteristics, including gender. Australia is a case in point, where the EEO law (1999) exists at the national and state levels across public and private organizations. Australian law makers advocate that employment for women should be managed based on merit and aim to eliminate discrimination against women in employment matters. The act requires private organizations employing over

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100 workers to report annually to a government authority on their progress in implementing EEO programs [82]. While many Western countries have similar EEO laws to Australia, many challenges still exist in most countries. Indeed, women remain underrepresented at all levels of leadership, politics, academia, and STEM industries (i.e., computer, mathematical, engineering, and life, physical, and social scientist occupations). According to Roy et al. [73], gender equality should not be a zero-sum game, meaning zero-sum conditions generate winners and losers whose goals are incompatible. This perspective insinuates a binary world consisting only of winners and losers; for example, where women gain, men lose. This mindset is diametrically opposed to gender equality, leading to unnecessary division and tension. Most certainly, gender equality is not a zero-sum game; it requires strategic human resource (HR) policies [73].

Consequently, this study examines gender equality within a professional environment. In particular, we have elected to investigate this disparity in a domain where women have historically faced underrepresentation and frequently exist as a marginalized cohort—the field of engineering [65]. Engineering is pivotal as it provides solutions for industries as varied as medicine, space, entertainment, and transportation. New inventions, implementation, and success factors depend on engineering to some extent. Thus, engineering is a research domain at the forefront of many perspectives. Engineering plays a substantial role in enabling Industry 4.0 and is instrumental in the "Green Industrial Revolution" and Industry 5.0. This domain offers the opportunity to tackle critical global issues and requires expert human capital equipped with comprehensive knowledge, skills, values, and attitudes that empower individuals [91]. Moreover, it necessitates the inclusion of the entire workforce—promoting gender equality by providing equal opportunities for both genders [55].

As a result, our study revolves around the following research questions: To what extent and through which systemic mechanisms are women subject to discrimination in the engineering domain? How do these factors align with or diverge from the objectives outlined in SDG 5 concerning the empowerment of women?

Tackling these questions is particularly prominent within the broader agenda of the UN SDG 5, which is committed to achieving gender equality and the empowerment of all women. Within this context, the research will shed light on how disparities in the engineering field contribute to or counteract the global objective of promoting gender equity. Next, our study's primary theoretical contribution lies in the nuanced interpretation of four central themes: "The Impact of Sex Differences on Productivity," "Gender Digital Divide," "Discriminatory Behaviour," and "Women and Performance." Unlike the extant literature which treats these themes in isolation, we provide a holistic synthesis, underscoring their interrelation and collective contribution to the persistence of the glass ceiling phenomenon. By doing so, we extend the existing body of knowledge on the glass ceiling and provide a fresh lens to understand its complexities. Moreover, from a practical standpoint, we introduce an integrated equality model. This model serves as a roadmap for organizations, enabling them to holistically address gender disparities. In doing so, not only do these entities enhance their internal diversity, but they also solidify their competitive positioning in the global market. Lastly, from macro and policy perspective, our findings and the proposed model possess implications for societal progress. By cultivating a more equitable engineering workforce, we edge closer to actualizing the UN's 2030 SDGs centered on global gender equality.

The subsequent sections of this manuscript provide a foundational overview of discrimination theories, followed by our research methodology, findings, discussion, and conclusion. Our findings emphasize the urgent need for greater gender balance in engineering leadership and call for a collective push from scholars, practitioners, and policymakers to bridge this divide.

II. Nature of Gender Inequality

Gender discrimination refers to treating people differently in their daily lives or at work because they are women or men. Such treatment is unacceptable when it violates the rights and freedoms to which every person is entitled under the "principles of equality" [89]. Discrimination can take many forms—overt, clearly discernible, subtler, and more covert [83]. While overt discrimination is illegal in most modern democracies, covert discrimination, with its less apparent manifestations, can perpetuate male domination over women [1].

A. Ingrained Gender Stereotypes and Hostile Environments

Centuries of patriarchal influences have deeply embedded gender stereotypes within the societal spirit, shaping perceptions and expectations related to roles, interests, and capabilities. This gendered framework significantly permeates professional environments [99]. From their formative years, children are gently but distinctly influenced by these biases. For example, boys frequently receive toys like trucks and tools, which subtly endorse technical and leadership trajectories [100], whereas girls are often oriented toward nurturing roles, exemplified by the dolls and kitchen sets they are commonly gifted [101]. As these girls' transition to womanhood and contemplate career avenues, the conspicuous scarcity of female figures in sectors such as engineering becomes evident.

The engineering sector, historically characterized by male predominance, manifests a self-sustaining loop: the scarcity of women results in an absence of relatable role models, rendering it increasingly arduous for aspiring females to envision themselves occupying such spaces [102]. Deep-seated societal norms, further propagated by media portrayals, educational systems, and familial influences, incline women's preferences toward professions that are perceived as more "people-oriented" [103]. This, in turn, implies a potential misfit for them in "thing-oriented" vocations like engineering [103].

The juxtaposition of societal expectations—encapsulating the role of nurturing caregivers and their professional identities—creates complex dilemmas for many women [32]. Consequently, a number of women might abstain from engineering careers due to anticipated demands such as prolonged working hours or the perception of minimal work–life balance (WLB) flexibility. Even within these fields, they may confront an incessant need to validate their worth, encountering scepticism, discrimination, or subtle microaggressions, which can make these workspaces

feel inhospitable [103]. Particularly in the realm of engineering, women's competencies might be doubted, their contributions might be trivialized, or their presence might be erroneously attributed to affirmative action policies. Such misperceptions often deter them from either entering or aspiring to leadership positions within the industry [103].

To surmount the challenges posed by ingrained gender stereotypes, early societal conditioning, and a scarcity of representation, a multipronged approach is imperative. Comprehensive solutions must span educational reforms, proactive mentorship programs, fostering inclusive work environments, and challenging long-standing societal prejudices, all converging toward industries that truly champion diversity and inclusion.

B. Gender Theories

Various theories in the extant literature identify distinct mechanisms that help explain gender discrimination. The stereotyping theory postulates that women's progress into leadership roles is restricted by the perceived differences between the characteristics of men and women [10]. This theory suggests that women are often deemed empathetic, emotional, dependent, less aggressive, unambitious, and lacking leadership traits. Attribution theory, rooted in psychology, examines how individuals identify the origins of everyday experiences. According to this theory, success or failure in the workplace is attributed to either stable factors (like intelligence, professionalism, and capabilities) or variable factors, such as luck being in the right place at the right time and offering an understanding of leadership dynamics. [10], [58]. Typically, workplace supervisors associate superior male performance that exceeds expectations with stable factors. Conversely, when females produce outstanding results, these outcomes are often attributed to variable factors. This assumption that high performance in females occurs by chance or good luck is inherently discriminatory [56].

HR climate strength theory [105], closely related to attribution theory, helps explain how past experiences of women engineers shape their expectations about future events. Regarding gender discrimination, this theory demonstrates how an HR system's strength, distinctiveness, consistency, and consensus in managing diversity influence employees' perceptions of the organization's diversity management efforts. HR must establish a robust, clear, consistent, and fair pathway to leadership that upholds gender equality. HR climate strength is built on perceptions, so according to this theory, an organization's success with gender equity programs can only be achieved when women believe that leadership positions are accessible and achievable.

The ongoing discourse around gender equality in professional sectors necessitates a detailed investigation of the pervasive barriers women encounter, especially in traditionally male-dominated domains. This narrative is exemplified within the engineering sector, where women's representation is may not be commensurate with their capabilities and qualifications [65]. The "Queen bee syndrome" and the "glass ceiling effect" are two seminal paradigms within the literature of gender studies that could shed light on the complexities of this discrepancy.

The "Queen bee syndrome" postulates a somewhat paradoxical behavior among women who have succeeded over the adversities of male-dominated professional landscapes. Once they have ascended to managerial or leadership positions, these women, rather than supporting the prospects of their female peers, may exhibit tendencies to guard their achieved status [37]. Drawing insights from the social identity theory, such behaviors are surmised to be coping mechanisms adopted by these "queen bees" to counteract identity threats inherent in male-biased environments. Significantly, individual accomplishments, including educational milestones and rapid career trajectories, serve as salient predictors of such tendencies [97]. Drexler [30] postulates that the emergence of the queen bee syndrome can be attributed to the overarching patriarchal structures that offer limited avenues for women's upward mobility. Once a few ascend these rarified echelons, they might inadvertently perpetuate the gender status quo to safeguard their niche.

Complementing the queen bee narrative is the pervasive phenomenon of the "glass ceiling." This metaphorical barrier acts as a challenging impediment for professional women (and other marginalized groups) aspiring for upper echelon roles, even when they possess the requisite qualifications and accolades [45]. Cotter et al. [21] seminal exploration posits this ceiling as a gender-centric impediment, distinct from racial or other discriminative barriers. This ceiling, while elusive and intangible, stems from entrenched institutional biases, deep-seated societal norms, and often tacit stereotypes favoring male hegemony [18], [74]. Organizations, despite their ostensible commitment to gender parity, may inadvertently sustain these barriers, thwarting women's progression.

In light of these theories, our research aims to harness the prism of the "glass ceiling." We posit that leveraging this theoretical framework will facilitate a more nuanced understanding of the different barriers, be they explicit or not, that women face in the field of engineering by looking at the available literature. Consequently, we present our central premise that women in engineering suffer from inequality in the engineering field.

III. Methodology

A. Sample of Articles and Data Collection

Our study aims to clarify the status of women in engineering, outline the issue of (in)equality in the field, delve into the underlying reasons for it, and provide recommendations for future research on the topic. To that end, we employ Callahan's [14] definition and guidelines of Cronin and George [22] of an integrative literature review. This systematic review concentrates on a "specific topic and employs a replicable methodology to unveil the intellectual structure of the research" [14, p. 301]. Consequently, we sought out articles published in top-tier journals that incorporated keywords related to "women," "female," and "(in)equality," as detailed in Fig. 1.

While searching the top journals in the field of engineering, our research adhered to the guidelines set forth by Bradford [12] and Garfield [36]. These authors asserted that papers published in top-tier journals were more likely to advance the research field. To identify these leading journals, we referenced the

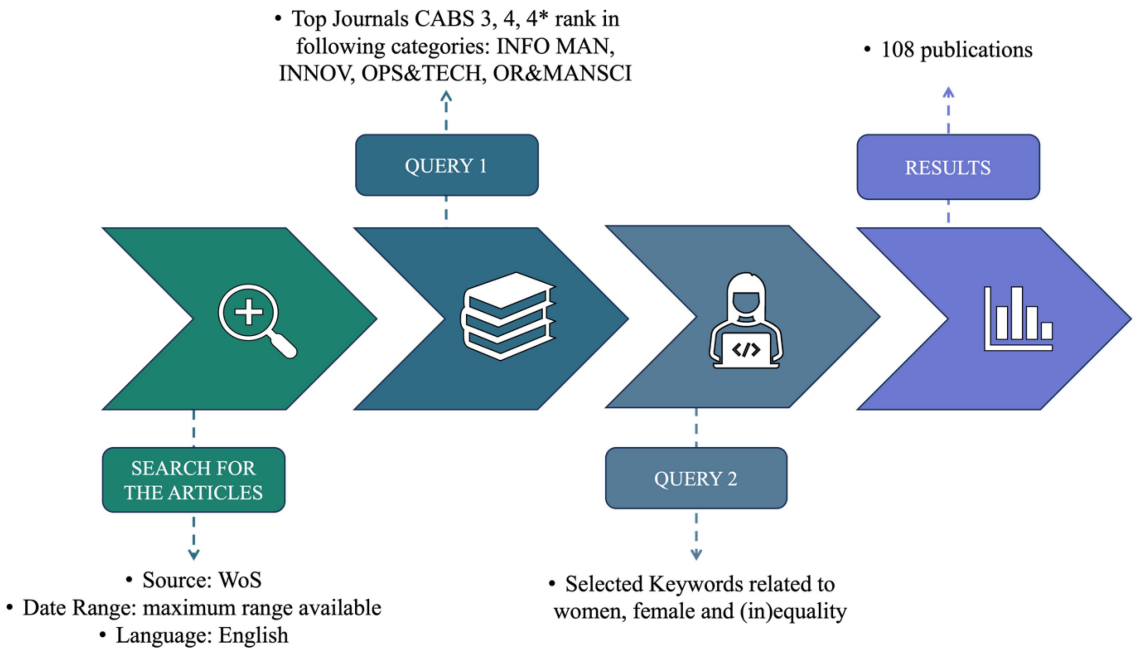

Fig. 1. Data collection process.

2021 journal ratings by the British Chartered Association of Business Schools' (CABS), considering only those rated three or above [25].

This search was conducted on June 15, 2023 and returned 108 articles. In line with Graneheim and Lundman [42], the selected articles were reviewed by six experienced researchers. For a thorough account of the process, refer to Supplementary Material, Table III.

B. Bibliometric Analysis

The bibliometric analysis was conducted using VOS viewer version 1.6.18. To gain a deeper understanding of the subject of women in engineering, we examined the frequency of authors' keywords. Co-occurrence analysis summarizes the core content by utilizing the most prevalent words within the articles [72]. In this analysis, a keyword had to appear at least three times to be considered. The bibliometric analysis reveals the relationships between authors' keywords—the more frequently a keyword occurs in conjunction with other keywords, the stronger their association [104]. This methodology aids in visualizing similarities more effectively and understanding the research field.

IV. Findings

A. Women in Engineering Domain Development

The period of publication (2005 to 2023) showed the following distribution: 9.26% from 2005 to 2011, 19.44% from 2012 to 2017, and 71.30% from 2018 to 2023 (see Fig. 2).

The distribution reveals an escalating interest in the field of women in engineering within top journals, providing additional substantiation for our review [87]. Interest in the topic became noticeable around 2012, with consistent attention from scholars over the subsequent 11 years. A steep rise was observed in 2018, which then dropped in 2020—likely due to COVID-19. Journals that notably contributed to the surge in the number of articles in 2021, 2022, and 2023 include *Technological Forecasting and Social Change*, *Research Policy*, and *Management Science* among others. The growing interest in this subject is both encouraging and crucial for attracting women to science. However, it is still insufficient, especially in the field of engineering. In our view, academic articles must push the boundaries of this research field as many aspects remain unexplored, making this topic ripe for further investigation.

Essential notion lies around the period between 1980s and early 1990s, when even though employment trends for women in information systems were promising, a gender discrimination persisted. For instance, women received lower salaries than men even when factors such as job level, age, education, and work experience were controlled. According to Goldin [39], even when factors such as childcare and education are factored in-women are at a disadvantage.

[107] analyzed the status quo of women in IT in the U.K.. Despite significant skill shortages in the industry, the authors reported a declining trend in the representation of women. They also found that while the IT industry does not actively exclude women, its gender programs lack strength, and companies do little to promote or retain them. The authors suggest that a possible explanation for the low representation of women in IT occupations is the declining number of female students graduating with a computer science degree.

One area that has consistently garnered scholarly attention over the past thirty years is gender pay inequality. A recent survey revealed that women engineers earn 20% less than their male counterparts in the U.K. [34]. Furthermore, the gender pay gap increases with age and experience, widening to 35%

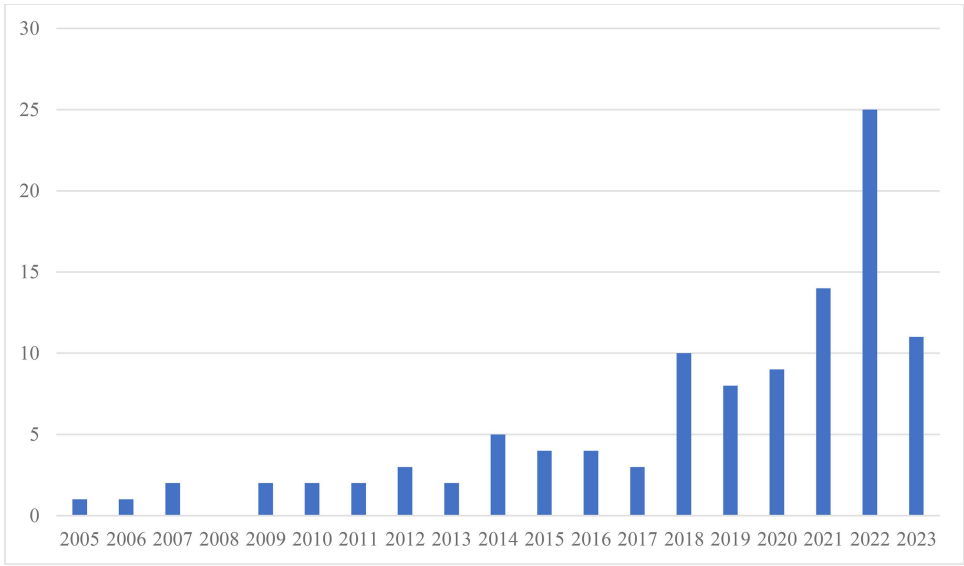

Fig. 2. Number of articles published per year.

TABLE I
JOURNAL FREQUENCIES, CITATIONS, AND (CABS) RATINGS

Journal	Frequency	Citations	CABS Rating
Management Science	37	921	4*
Research Policy	16	474	4*
Technological Forecasting and Social Change	14	172	3
Journal of Technology Transfer	6	182	3
Information Society	4	94	3
Information Technology & People	4	46	3
Journal of the Association for Information Systems	4	19	4*
Information Systems Frontiers	3	24	3
Journal of Computer-Mediated Communication	3	75	3
Annals of Operations Research	2	6	3
European Journal of Information Systems	2	4	4
Government Information Quarterly	2	109	3
Technovation	2	21	3
IEEE Transactions on Engineering Management	1	11	3
Industry and Innovation	1	6	3
Journal of Purchasing and Supply Management	1	7	3
Journal of Strategic Information Systems	1	11	4
Journal of the Association for Information Science and Technology	1	21	3
Manufacturing & Service Operations Management	1	62	3
Production and Operations Management	1	23	4
R&D Management	1	10	3
Supply Chain Management	1	3	3
TOTAL	**108**	**2301**	

for women aged 55 and above, exposing twofold discrimination based on gender and age [34]. While women are attracted to the engineering profession for similar reasons as their male counterparts—for instance, excelling at maths and science in school and desiring attractive, well-paid professional opportunities in the future—their ambitions for remuneration may be misplaced. In many countries, women are unlikely to receive the same pay as their male counterparts [77]. Not surprisingly, recent publications address the impact of the COVID-19 pandemic on women's research productivity [24], [93].

Table I shows the journals, frequency, citations and their ABS ratings. Only the top three journals have more than seven articles dealing with women in engineering in a 19-year research period (*Management Science, Research Policy, Technological*

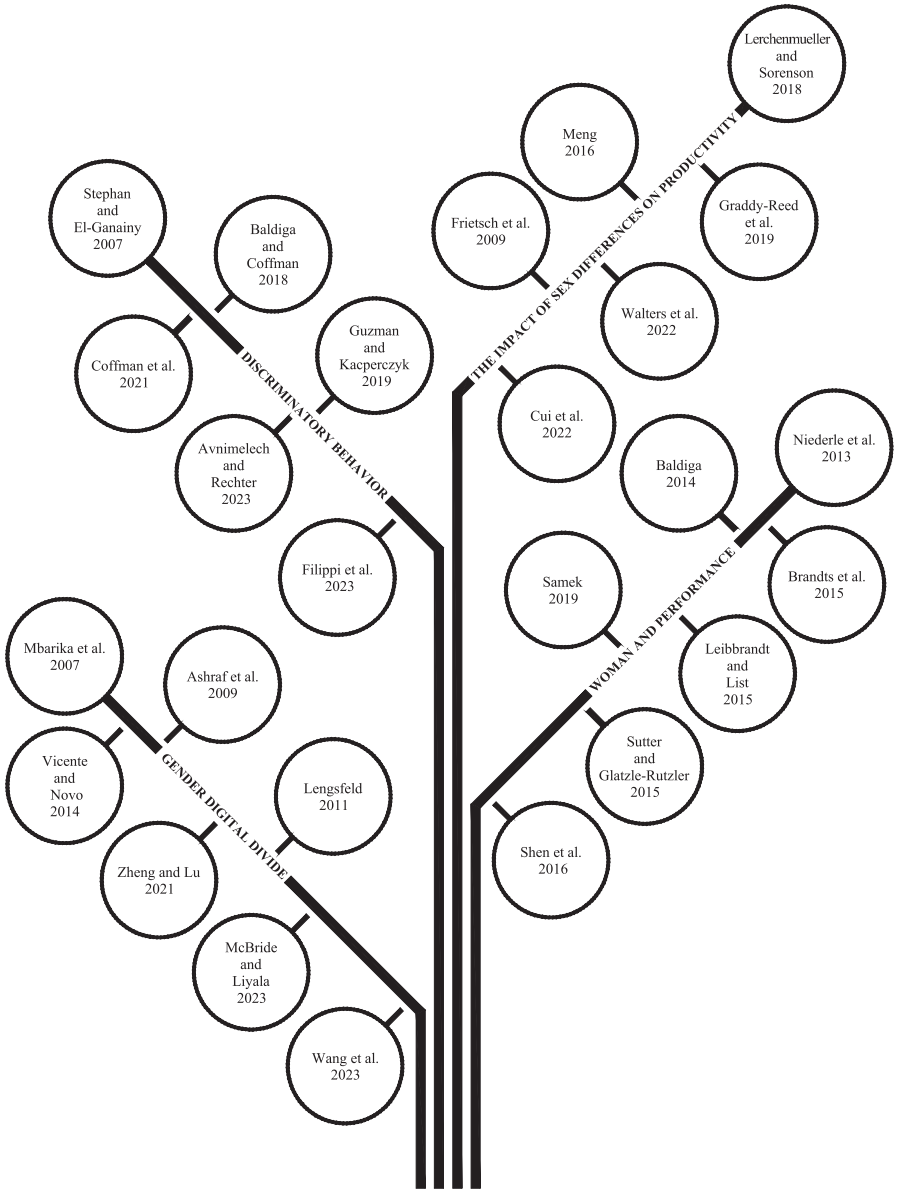

Fig. 3. Most influential authors.

Forecasting and Social Change). These three journals comprise 62.04% of all publications on this topic in the top journals (see Table I). *Management Science* has the most articles (37) in this field and the most cited articles (921 citations).

Special issues in scientific journals, also referred to as thematic and monographic issues, assist in inquiring more intensely into a specific topic [64]. One or more editors usually pilot a special issue with expertise in the topic. These guest editors typically replace the regular editor-in-chief. Thus, special issues on *Women in Science* and *Women in Engineering* in top journals could stimulate more scholarship and help make a substantial contribution to the further development of this research field.

B. Intellectual Structure of Women in Engineering

Table II and Fig. 3 illustrate the intellectual structure of women in engineering. An in-depth analysis of the selected articles revealed four themes worthy of attention: "*The impact of sex differences on productivity*," "*Gender digital divide*," "*Discriminatory behavior" and "Women and performance*." The most frequent keywords, and significance of each topic will now be discussed.

C. Impact of Sex Differences on Productivity

Gender equity in academia is a long-standing issue. While prevalent in all professions, the effects of discrimination are particularly evident in STEM fields. O'Connell and McKinnon [70] recently confirmed that fundamental barriers to career progression exist across nations and career stages in STEM fields. The authors found that ingrained biases, stereotypes, double standards, bullying, and harassment are prevailing issues in STEM fields, eroding women's self-efficacy. Furthermore,

TABLE II
TOPIC, NOTABLE REFERENCES, AND MAIN CONCLUSIONS

Topic	Descriptor	Notable References	Main Conclusions
The impact of sex differences on productivity	Gender, impact, innovation, productivity, education, faculty, research productivity	Frietsch et al. [35], Meng [62], Lerchenmueller and Sorenson, [54], Graddy-Reed et al. [41], Cui et al. [24], Walters et al. [93]	• Women are 20% less likely to become principal investigators compared to men. Around 60% of this gap can be attributed to differences in productivity. • Gender inequality remains persistent in later professional outcomes despite equal enrolment of both sexes in life science graduate programs. • During the COVID-19 pandemic, while overall research productivity increased, female scholars experienced a 13.2% decline in productivity compared to their male counterparts. Women's academic productivity decreased due to increased administrative tasks, teaching responsibilities, and traditional household roles.
Gender digital divide	Gender inequality, digital divide, technology, ICT,	Mbarika et al. [60], Ashraf et al. [5], Lengsfeld [53], Choi and Park [19], Vicente, and Novo [92], Zheng and Lu [98], McBride and Liyala [61], Wang et al. [94]	• Women are optimistic and willing to embrace ICT as a practical tool to enter the labor market, but public policies often fail to deter gender discrimination in the workplace. • As husbands migrate for work, women left behind experience an increase in decision-making authority, leading to improved gender equality within households. • Social media can play a crucial role in facilitating financial support, particularly for women entrepreneurs and individuals with limited connections.
Discriminatory behavior	Female managers, motivation, socialization, entrepreneurship, returns, attitudes	Stephan and El-Ganainy [78], Baldiga and Coffman [9], Guzman and Kacperczyk [43], Coffman et al. [20], Avnimelech and Rechter [7], Filippi et al. [33]	• Women have a slight advantage over men because they are less likely to be replaced by automation. • The research uncovered discriminatory behavior, revealing that employers prefer equally qualified male candidates over female candidates when hiring.
Women and performance	Gender differences, discrimination, labor market, decision-making, competitiveness	Niederle et al. [67], Baldiga [8], Brandts et al., [13], Leibbrandt and List [52], Sutter and Glatzle-Rutzler [81], Shen et al., [76], Samek [75]	• The stereotype of women being less successful in digital games may lead to unequal participation, despite the lack of real performance differences between men and women in massively multiplayer online games. • Research on gender and competitiveness suggests that women are less likely to apply for jobs that include competitive compensation schemes, such as pay for performance.

TABLE III
GENDER DIFFERENCES OF EDITORS-IN-CHIEF IN TOP JOURNALS

Journal	Man	Woman
Management Science	1	
Research Policy	9	4
Technological Forecasting and Social Change	1	1
Journal of Technology Transfer	5	
Information Society	1	
Information Technology & People	3	1
Journal of the Association for Information Systems		1
Information Systems Frontiers	2	
Journal of Computer-Mediated Communication		1
Annals of Operations Research	1	
European Journal of Information Systems	1	
Government Information Quarterly	2	
Technovation	1	1
IEEE Transactions on Engineering Management	1	
Industry and Innovation		2
Journal of Purchasing and Supply Management	1	1
Journal of Strategic Information Systems		1
Journal of the Association for Information Science and Technology	1	
Manufacturing & Service Operations Management		1
Production and Operations Management	1	
R&D Management	2	
Supply Chain Management	1	2
TOTAL	**34**	**16**

they identified STEM fields as being unfriendly toward family-life, compelling women to choose between starting a family or advancing a career. Participants in this study perceived their academic journey in STEM as different from their male colleagues, in that many of the typical obstacles faced by women were not present for men. In agreement, Stoeger et al. [80] argue that while some of these impediments are surmountable through mentoring and networking, overcoming the barriers will generally require a cultural shift in the values and norms currently hindering progress towards equity and inclusion in STEM academia.

Walters et al. [93] studied the drop-in women's academic productivity, in terms of time spent on research and publications, at the beginning of the COVID-19 pandemic in South Africa. Their findings showed that the decline in research activity was primarily due to an increase in administrative tasks, teaching, and traditional household roles, which inhibited women from further academic work. Cui et al. [24] also studied the impact of lockdown on research productivity in the United States. The authors highlighted that although total research productivity increased during the COVID-19 pandemic, the productivity of female scholars dropped by 13.2% compared to their male colleagues.

Graddy-Reed et al. [41] explored publication productivity differences between male and female science graduate students, discovering that men are awarded publications three times more often than their female colleagues. Meng's [62] research also focused on collaboration to understand the gender gap in academic patenting, finding that collaboration with industry was the most significant activity for female academic scientists.

The lack of women in leadership roles and on editorial boards has been recognized as an issue. It has been found that women make up only 32% of editors-in-chief in top engineering journals (see Table III). A significant portion of the gender gap in academia appears to occur during the transition from post-doctoral student to principal investigator. Women become principal investigators at a rate 20% lower than men and receive less credit for their citations [54], [70].

Women engineers facing discrimination in academia is not a unique circumstance; the corporate world does not fare much better. For instance, women represent only 5% of global CEOs [59]. A recent Australian study revealed that despite the mounting evidence about the economic benefits of gender equality, Australian corporations are not making sufficient progress toward achieving gender balance in senior leadership. This study is based on the perspectives of women in key senior positions, emphasizing that despite the existing Australian Workplace Gender Equality legislation, unconscious bias remains a significant barrier to women attaining top leadership roles. Moreover, the findings of this study contribute to understanding the routines that reinforce the enduring gender order in business, solidifying men's continued dominance in organizational hierarchies. Indeed, the World Economic Forum [96] underlines the importance of gender equality as a catalyst for new opportunities in the Fourth Industrial Revolution. The key to success lies in enhancing the diversity of the talent pool by promoting the inclusion of women and girls in STEM disciplines.

D. Gender Digital Divide

Women and girls often face limited opportunities to acquire digital skills. Novo-Corti et al. [69] concluded that rural women in Spain are aware of the importance of ICT in decision-making

processes and everyday life. However, barriers such as income, Wi-Fi connectivity, and education lead to inadequate ICT skills, affecting their ability to find a job. Moreover, the study highlighted the importance of technology access for rural women in promoting gender equality [69].

Subsequently, the research shifted focus to information technology in the context of the gender gap in ICT engineering. Computers have created a symbolic association between masculinity, gender norms, values, technology, and ICT [17]. According to Lagesen [50], computers and ICT form a cycle that reinforces the inclusion of men in ICT. There is a pressing need to disrupt this cycle and inspire women to engage with ICT.

Mbarika et al. [60] demonstrated that women in regions as remote as Sub-Saharan Africa are optimistic and willing to embrace ICT with proper support. These women perceive ICT as a practical tool to enter the labor market. Overall, the evidence supports the notion that the most significant obstacles for these women in ICT are public policies that have failed to combat gender discrimination in the workplace, thus severely restricting the development of the ICT sector.

Gender disparities in information technology can exacerbate power imbalances within families and contribute to the digital divide, especially in rural areas of China where male migration to urban centers for work is prevalent. Zheng and Lu's [98] research suggests that when husbands migrate, the decision-making authority of the women left behind increases, thereby promoting gender equality within households. However, Ashraf et al. [5] highlighted the Bangladeshi community's interest in ICT interventions, but the results revealed challenges due to gender discrimination and cultural barriers. In contrast, Lengsfeld [53] examined the digital divide in an extensive cross-national analysis in 25 countries and found only minor gender inequality.

Choi and Park [19] studied gender disparities in the utilization of the central government website in Korea. Their findings suggest that while there's no enduring gender inequality in accessing e-government services, there's a digital divide concerning the availability and utilization of these services based on education and occupation. In contrast, Vicente and Novo [92] studied the extent of social and political participation on the internet in Spain, revealing a significant gender disparity.

Recently, Lagesen et al. [49] reviewed inclusion strategies aimed at reducing the gender gap in ICT engineering in academia. They found that substantial efforts are often needed for these initiatives to yield successful and sustainable outcomes. They concluded that gender-balanced programs are more likely to retain both men and women. In their study, Wang et al. [94] explored the potential impact of social media utilization on funding outcomes for women-led firms. Their research findings suggest that platforms like Twitter can play a vital role in facilitating financial support, particularly for women entrepreneurs and individuals with limited connections. This is attributed to the ability of social media to reduce information asymmetry between founders and potential investors.

E. Discriminatory Behavior

While this study aims to determine why women are excluded from engineering, one explanation could be the implicit barriers, or glass ceiling [21]. Human capital theory suggests that women may not be promoted because they have fewer career investments than males, although this was recently challenged by Goldin [39]. However, Neokosmidis et al. [66], through the lens of the Artificial Bee Colony (i.e., drawing on gender evolution), controversially argue that the gender gap is consistently decreasing, with women performing better in STEM. Furthermore, Guzman and Kacperczyk's [43] analysis reveals a significant difference between female-led and male-led ventures in securing external financing, particularly venture capital. Businesses led by women are 63% points less likely to receive such financing.

Studies have also explored behavioral decision-making. Results showed that sponsorship programs only encouraged men's willingness to compete—not women's [9]. Coffman et al. [20] found evidence of discriminatory behavior in their research, as employers show a discernible bias, favoring equally competent male candidates over their female counterparts when making hiring decisions. In contrast, Filippi et al. [33] studied the potential risk of automation technologies replacing human workers in Europe. Their findings show that the gender gap in the risk of substitution favors women, meaning that women are slightly less likely to be replaced by automation compared to men.

According to researchers in this field, the perception of computing as technical and male-dominated persists. Thus, "access" [10] appears to be a challenge where filters prevent females from pursuing computing as a career [106]. Counteracting this hypothesis, Imhof et al. [46] argue that the gender gap is closing as far as female access and self-efficacy in computer science are concerned. This study found that female and male students report comparable computer usage for their studies. However, "User Behavior" emerged as gender-specific, with males spending more personal time at the computer. Male students also outperformed female students in a specific computer task. Consequently, although access issues persist, improvements are being made. Yet, "treatment" [10] remains a substantial issue in IT.

Early scholarly interest in women in engineering during the early 90s focused on internet studies. From the inception of computerization, there has been attention given to gender differences in computer behavior concerning computer access, computer use, motivation, and computer self-efficacy. Imhof et al. [46] found that by the beginning of the new millennium, the gender gap concerning access and self-efficacy was closing. However, the focus has shifted from computer access and self-efficacy issues to smartphone use and adoption [2]. This literature agrees that a general gender gap exists in smartphone adoption [3].

F. Women and Performance

Within this topic, authors have studied gender performance differences in digital games with a specific focus on progression speed. The stereotype of female players as less successful can lead to unequal participation, particularly when studies show no significant differences in participation or performance between men and women in massive multiplayer online games [76]. Moreover, studies reveal a gender difference in competitiveness [13], [75].

Research concerning gender and competitiveness indicates that women may feel discouraged from applying for jobs

when competitive compensation schemes, such as pay-for-performance, are involved [75]. This difference in competitiveness could contribute to the gender gap in labor market outcomes. Samek [75] explored the impact of compensation schemes on job application willingness and discovered that pay-for-performance schemes tend to discourage women from applying for positions that employ these schemes. Additionally, incentive schemes have been found to affect women's and men's performance differently [11], [39]. One commonly offered explanation for the persistent gender wage gap in labor markets is that women often avoid wage negotiations. Leibbrandt and List's [52] findings show that in situations where it is not explicitly indicated that wages are negotiable, men tend to negotiate for higher wages more than women do. Conversely, women are more likely to signal their acceptance of a lower salary.

However, Goldin's work on gender pay disparities provides a comprehensive history of gender labor-market inequality over the past 200 years. Goldin has overturned assumptions about both historical gender relations and what is required to achieve greater equality in the present day [85]. Goldin's work reveals that enormous gains made by women in the workplace over time; however, concludes true equity remains out of reach [29].

Consequently, women's attitudes toward pay-for-performance should be a central consideration for HR managers when setting up remuneration programs and recruitment plans. A more recent body of gender research has delved into gender differences in competitiveness (c.f. [109]). Indeed, growing evidence shows a gender gap in entry into competition [13]. Furthermore, mentors are more likely to discourage women from entering early into competition, promotions, and the like. According to Brandts et al. [13, p. 1018], "this gender gap is mainly driven by high-performing women entering too little and low-performing men entering too often." Croson and Gneezy [23] suggest that a crucial factor is men's relatively higher overconfidence compared to women. Another possible explanation, particularly if the mentor is female, could be attributed to the queen bee syndrome (mentioned above), where women are more likely to dissuade other women from advancing in their careers [13]. Intriguingly, North and Noyes [68] investigated children's competitive mindsets towards computers and concluded that there was no gender gap between girls and boys aged 11 and 12.

V. Discussion and Conclusion

This study aimed to delve into the complex topic of gender inequality in engineering. In doing so, we utilized a series of bibliometric indicators to visualize similarities, providing an overview of this field of study. Thus, our study found evidence that women in engineering were discriminated against and suffered varying degrees of inequality.

In particular, this study highlighted the differences between the number of women in other STEM disciplines compared to engineering. The attractiveness of engineering as a career for women appears to be attributed to several factors, most notably pay differentiation, limited career potential, and a hostile male environment that is not family-friendly ([93]. We detected that discrimination against women in engineering leadership roles is typically covert (c.f. [83]), where less apparent signs can mainly mask male domination over women [1]. The glass ceiling hinders women's access to organizational promotions and leadership roles [21], [71]. This phenomenon is not just an isolated issue within the sector; it is emblematic of the deeply entrenched biases that often subconsciously favor men in leadership positions in engineering [15]. These biases deny deserving women the opportunity to ascend the ranks and deprive organizations of the diverse perspectives and approaches women bring to the table. The failure to shatter glass ceiling could result in significant losses for the industry, from missed innovations to decreased profitability.

Similarly, our findings are supported by stereotyping theory [10], which also curtails and rationalizes women's progression to the prestigious C-suite. While stereotyping was apparent in several studies we analyzed, we did not find convincing support for attribution theory [10], where women's success is perceived to be due to luck rather than talent or capabilities. Likewise, we did not see strong evidence for the queen bee theory [37]. The lack of evidence for attribution theory and queen bee theory could be due to insufficient women having reached the C-suite in engineering to test these theories. We needed more information to identify evidence in the literature on HR climate strength theory [105]. Ultimately, the study yields toward considering HR gender policies based on overcoming the glass ceiling as a vital approach in managing gender inequity– -particularly in the domain of engineering. As such, addressing and dismantling the glass ceiling is not just a matter of gender equity; it calls for a crucial new HR policy strategy for the continued growth and innovation of the engineering sector as a whole.

A. Introducing a New HR Policy for Gender Management

An effective policy is needed to address the glass ceiling effect in engineering. This policy must address the current limitations in engineering that make the profession unattractive for women and unsustainable. An effective policy should overcome these barriers and lift the glass ceiling for incumbents. Our policy model has the following five key recommendations (see Fig. 4).

1) Creating a new policy starts with fairness in recruitment. A diverse panel can offer a broader perspective and reduce potential biases [95]. While affirmative action policies can be controversial, they can increase the number of women until a natural balance is achieved [74].
2) Promoting WLB is pivotal in attracting and retaining women in engineering. Flexible hours allow female engineers to manage their time effectively, addressing professional and personal commitments. As part of WLB, remote working options cater to the diverse needs of women, especially those who have responsibilities at home or live in areas with commuting challenges. Generous parental leave, on the other hand, ensures that women do not have to choose between their career and family.
3) The individual employee performance management system should be overhauled as part of the policy. Performance management refers to the various activities, policies, procedures, and interventions designed to help

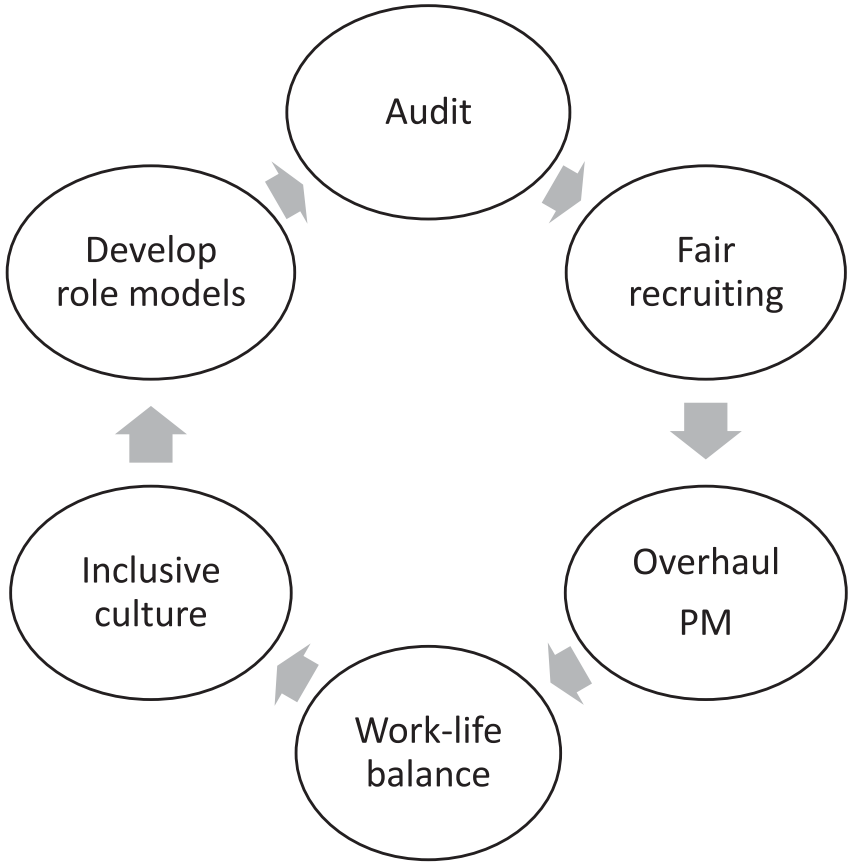

Fig. 4. HR policy for gender management.

employees improve their performance. These programs begin with performance appraisals but also include feedback, goal setting, training, and reward systems [28, p. 42]. The performance management process is pivotal to overcoming many of the current issues for women in engineering. Regular training sessions on recognizing and combating unconscious biases can be instrumental in performance management, addressing not only gender biases but also other forms of discrimination. More specifically, leadership training and professional development tailored to women can give them the requisite skills and confidence to target and attain higher positions [44], [83]. In order to ensure fair decisions are made about pay in performance reviews, regular audits should be conducted, addressing any disparities promptly [64]. Finally, the most critical part of the performance process is feedback. It is crucial to clearly define and communicate the criteria for promotions, ensuring transparency and reducing unconscious biases in decision-making. Regular feedback mechanisms allow employees to voice their concerns, ensuring that potential glass-ceiling issues are promptly addressed (Maley, 2019).

4) It is paramount to cultivate an environment of inclusivity in the workplace culture that values and respects diversity. This can be fostered through training and by creating safe channels for reporting discrimination or harassment [83]. Furthermore, the policy model will benefit from collaboration between universities and colleges to support and encourage female students in engineering, ensuring a consistent flow of female talent into the industry.
5) Role models should be identified, highlighting and celebrating the achievements of female engineers as role models, showcasing that leadership roles are attainable for women in the field. Similarly, mentorship programs can be designed to pair up-and-coming female engineers with experienced professionals who can offer guidance and advocacy [32].

Such practices support women in their professional journey and acknowledge their multifaceted societal roles. By incorporating these measures, engineering companies can create an inclusive environment where women feel valued and empowered to thrive.

B. Future Studies

Future empirical studies exploring gender inequity in male-dominated professions such as engineering are pivotal to driving transformative change in academia and the corporate world. There is a pressing need for research encompassing qualitative and quantitative methodologies. Qualitative studies could be employed to unearth the nuanced experiences of women in engineering. Personal narratives, in-depth interviews, and ethnographic studies could shed light on women's implicit difficulties, offering a more comprehensive understanding of the systemic

issues. Quantitative research could help in mapping the extent of the disparities. Surveys and large-scale data analyses can offer statistical evidence of the gaps in pay, opportunities, and representation, enabling stakeholders to set clear targets for improvement.

Furthermore, longitudinal studies that track women's progress over time could offer insights into the long-term effects of interventions and policies. These studies can evaluate the sustainability of implemented changes and their long-term impact on gender equity in engineering. In conclusion, to authentically address the issue of gender inequity in engineering, a holistic research approach is essential. It should encompass diverse methodologies, focus on micro- and macro-level issues, and adopt a global perspective. Only then can we create a more inclusive, equitable, and just engineering profession for all.

In conclusion, gender equity is a crucial driver of innovation and vital for the progression of science. However, despite extensive research and governmental policies, gender inequality remains a critical issue across the global workplace [39], particularly in engineering, where the industry suffers from a stark gender imbalance. This issue presents a significant challenge for governments, organizations, and society at large, as the gender imbalance hinders the progression of this critical profession. Greater inclusion of women in engineering will enhance diversity and bring social and economic value to the profession and society [50]. It will also boost innovative outcomes and the talent pool [108]. Reducing the gender gap in engineering will also legitimize and help reinforce hierarchical relations between men and women.

Moreover, addressing the gender imbalance in engineering could be one of the most critical undertakings in achieving the UN's 2030 Sustainable Development Goal's fifth objective—gender equality. This goal ensures women's equal opportunities for progression to leadership and promotes the use of enabling technology to empower women. Achieving gender equality in engineering leadership is a pressing and urgent matter. Thus, we aim to realize Ban Ki-moon's judicious aspiration of a shared vision of humanity and a social contract between the world's leaders and the people.

REFERENCES

[1] M. G. Alkadry and L. E. Tower, "Covert pay discrimination: How authority predicts pay differences between women and men," *Public Admin. Rev.*, vol. 71, no. 5, pp. 740–750, 2011.

[2] N. Ameen, R. Willis, and M. Hussain Shah, "An examination of the gender gap in smartphone adoption and use in Arab countries: A cross-national study," *Comput. Hum. Behav.*, vol. 89, pp. 148–162, 2018.

[3] M. Ansari, Y. Alas, G. Hardaker, J. H. Jardin, M. Smith, and A. D. Ahad, "Smartphone habit and behavior in Brunei: Personalization, gender, and generation gap," *Comput. Hum. Behav.*, vol. 64, pp. 719–727, 2016.

[4] P. R. Arvate, G. W. Galilea, and I. Todescat, "The queen bee: A myth? The effect of top-level female leadership on subordinate females," *Leadership Quart.*, vol. 29, no. 5, pp. 533–548, 2018.

[5] M. Ashraf, J. Hanisch, and P. Swatman, "ICT intervention in the 'Chandanbari' Village of Bangladesh: Results from a field study," *Inf. Syst. Front.*, vol. 11, pp. 155–166, 2009.

[6] AAUW, "The STEM gap: Women and girls in science, technology, engineering and math," 2021. Accessed: Jan. 14, 2021, [Online]. Available: https://www.aauw.org/resources/research/the-stem-gap/

[7] G. Avnimelech and E. Rechter, "How and why accelerators enhance female entrepreneurship," *Res. Policy*, vol. 52, no. 2, 2023, Art. no. 104669.

[8] K. Baldiga, "Gender differences in willingness to guess," *Manage. Sci.*, vol. 60, no. 2, pp. 434–448, 2014.

[9] N. R. Baldiga and K. B. Coffman, "Laboratory evidence on the effects of sponsorship on the competitive preferences of men and women," *Manage. Sci.*, vol. 64, no. 2, pp. 888–901, 2018.

[10] J. J. Baroudi and G. E. Truman, "Gender differences in the information systems managerial ranks: An assessment of discriminatory practices," *MIS Quart.*, vol. 18, pp. 129–142, 1992.

[11] M. Bennedsen, E. Simintzi, M. Tsoutsoura, and D. Wolfenzon, "Do firms respond to gender pay gap transparency?," *J. Finance*, vol. 77, no. 4, pp. 2051–2091, 2022.

[12] S. C. Bradford, "Sources of information on specific subjects," *Engineering*, vol. 137, pp. 85–86, 1934, Reprinted in Collection Management, pp. 1, 95-103.

[13] J. Brandts, V. Groenert, and C. Rott, "The impact of advice on women's and men's selection into competition," *Manage. Sci.*, vol. 61, no. 5, pp. 1018–1035, 2015.

[14] J. L. Callahan, "Constructing a manuscript: Distinguishing integrative literature reviews and conceptual and theory articles," *Hum. Resour. Develop. Rev.*, vol. 9, no. 3, pp. 300–304, 2010.

[15] M. T. Cardador and B. Caza, "The subtle stressors making women want to leave engineering," Harvard. Bus. Rev., 2018.

[16] B. J. Casad et al., "Gender inequality in academia: Problems and solutions for women faculty in STEM," *J. Neurosci. Res.*, vol. 99, no. 1, pp. 13–23, 2020.

[17] E. Chang, *Brotopia: Breaking Up the Boys' Club of Silicon Valley*. New York, NY, USA: Portfolio, 2018.

[18] M. A. Chisholm-Burns, C. A. Spivey, T. Hagemann, and M. A. Josephson, "Women in leadership and the bewildering glass ceiling," *Amer. J. Health-System Pharm.*, vol. 74, no. 5, pp. 312–324, 2017.

[19] Y. T. Choi and S. Park, "Understanding gender inequality in central e-government: A Korean case study," *Government Inf. Quart.*, vol. 30, no. 3, pp. 300–309, 2013.

[20] K. B. Coffman, C. L. Exley, and M. Niederle, "The role of beliefs in driving gender discrimination," *Manage. Sci.*, vol. 67, no. 6, pp. 3551–3569, 2021.

[21] D. A. Cotter, J. M. Hermsen, S. Ovadia, and R. Vanneman, "The glass ceiling effect," *Social Forces*, vol. 80, no. 2, pp. 655–681, 2001.

[22] M. A. Cronin and E. George, "The why and how of the integrative review," *Organizational Res. Methods*, vol. 26, no. 1, pp. 168–192, 2023.

[23] R. Croson and U. Gneezy, "Gender differences in preferences," *J. Econ. Literature*, vol. 47, no. 2, pp. 448–474, 2009.

[24] R. Cui, H. Ding, and F. Zhu, "Gender inequality in research productivity during the COVID-19 pandemic," *Manuf. Service Operations Manage.*, vol. 24, no. 2, pp. 707–726, 2022.

[25] M. Dabić, B. Vlacic, J. Paul, S. Sahasranamam, L.-P. Dana, and B. Glinka, "Immigrant entrepreneurship: A review & agenda for future research," *J. Bus. Res.*, vol. 113, pp. 25–38, 2020.

[26] S. Daher-Nashif and H. Bawadi, "Women's health and well-being in the United Nations sustainable development goals: A narrative review of achievements and gaps in the Gulf states," *Int. J. Environ. Res. Public Health*, vol. 17, no. 3, 2020, Art. no. 1059.

[27] C. De Smith, "Economist Claudia Goldin wins Nobel Prize for tracking American women's labor participation over centuries, evolution of wage gap," *Harvard Gazette*, Oct. 14, 2023.

[28] A. S. DeNisi and K. R. Murphy, "Performance appraisal and performance management: 100 years of progress?," *J. Appl. Psychol.*, vol. 102, no. 3, pp. 421, 2017.

[29] C. DeSmith, "Those inequalities are inequalities that occur within households," The Harvard Gazete, 2023. [Online]. Available: https://news.harvard.edu/gazette/story/2023/10/harvard-claudia-goldin-recognized-with-nobel-in-economic-sciences/

[30] P. Drexler, "The tyranny of the queen bee," *Wall Street J.*, vol. 6, no. 6, 2013, Art. no. 8.

[31] N. Ellemers, H. Van den Heuvel, D. De Gilder, A. Maass, and A. Bonvini, "The underrepresentation of women in science: Differential commitment or the queen bee syndrome?," *Brit. J. Social Psychol.*, vol. 43, no. 3, pp. 315–338, 2004.

[32] K. J. Evans and J. F. Maley, "Barriers to women in senior leadership: How unconscious bias is holding back Australia's economy," *Asia Pacific J. Hum. Resour.*, vol. 59, no. 2, pp. 204–226, 2021.

[33] E. Filippi, M. Bannò, and S. Trento, "Automation technologies and the risk of substitution of women: Can gender equality in the institutional context reduce the risk?," *Technol. Forecasting Social Change*, vol. 191, 2023, Art. no. 122528.

[34] N. Fleming, "How the gender pay gap permeates science and engineering," *New Scientist*, vol. 237, no. 3167, pp. 22–23, 2018.

[35] R. Frietsch, I. Haller, M. Funken-Vrohlings, and H. Grupp, "Gender-specific patterns in patenting and publishing," *Res. Policy*, vol. 38, no. 4, pp. 590–599, 2009.

[36] E. Garfield, "How ISI selects journals for coverage: Quantitative and qualitative considerations," *Inf. Scientist*, vol. 13, no. 22, pp. 185–193, 1990.

[37] D. E. Gibson and D. I. Cordova, "Women's and men's role models: The importance of exemplars," in *Mentoring Dilemmas*. London, U.K.: Psychology Press, 1999, pp. 135–154.

[38] C. Glass and A. Cook, "Leading at the top: Understanding women's challenges above the glass ceiling," *Leadership Quart.*, vol. 27, no. 1, pp. 51–63, 2016.

[39] C. Goldin, *Career and Family: Women's Century-Long Journey Toward Equity*. Princeton, NJ, USA: Princeton Univ. Press, 2021.

[40] L. O. Gostin and E. A. Friedman, "The sustainable development goals: One-health in the world's development agenda," *Jama*, vol. 314, no. 24, pp. 2621–2622, 2015.

[41] A. Graddy-Reed, L. Lanahan, and J. Eyer, "Gender discrepancies in publication productivity of high-performing life science graduate students," *Res. Policy*, vol. 48, no. 9, 2019, Art. no. 103838.

[42] U. H. Graneheim and B. Lundman, "Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness," *Nurse Educ. Today*, vol. 24, no. 2, pp. 105–112, 2004.

[43] J. Guzman and A. O. Kacperczyk, "Gender gap in entrepreneurship," *Res. Policy*, vol. 48, no. 7, pp. 1666–1680, 2019.

[44] M. Hersh, "The changing position of women in engineering worldwide," *IEEE Trans. Eng. Manage.*, vol. 47, no. 3, pp. 345–359, Aug. 2000.

[45] C. Hymowitz and T. D. Schellhardt, "The glass ceiling: Why women can't seem to break the invisible barrier that blocks them from the top jobs," *Wall Street J.*, vol. 24, no. 1, pp. 1573–1592, 1986.

[46] M. Imhof, R. Vollmeyer, and C. Beierlein, "Computer use and the gender gap: The issue of access, use, motivation, and performance," *Comput. Hum. Behav.*, vol. 23, no. 6, pp. 2823–2837, 2007.

[47] A. Keune, K. A. Peppler, and K. E. Wohlwend, "Recognition in makerspaces: Supporting opportunities for women to "make" a STEM career," *Comput. Hum. Behav.*, vol. 99, pp. 368–380, 2019.

[48] F. Küskü, M. Özbilgin, and L. Özkale, "Against the tide: Gendered prejudice and disadvantage in engineering," *Gender, Work Org.*, vol. 14, no. 2, pp. 109–129, 2007.

[49] A. Lagesen, I. Pettersen, and L. Y. Berg, "Inclusion of women to ICT engineering-lessons learned," *Eur. J. Eng. Educ.*, vol. 47, no. 3, pp. 467–482, 2022.

[50] V. A. Lagesen, "Making positive circles of inclusion," *Women Comput. Sci. Gender Culture Asia*, vol. 3, pp. 27–42, 2019.

[51] D Le Blanc., "Towards integration at last? The sustainable development goals as a network of targets," *Sustain. Develop.*, vol. 23, pp. 176–187, 2015.

[52] A. Leibbrandt and J. A. List, "Do women avoid salary negotiations? Evidence from a large-scale natural field experiment," *Manage. Sci.*, vol. 61, no. 9, pp. 2016–2024, 2015.

[53] J. H. B. Lengsfeld, "An econometric analysis of the sociodemographic topology of the digital divide in Europe," *Inf. Soc.*, vol. 27, no. 3, pp. 141–157, 2011.

[54] M. J. Lerchenmueller and O. Sorenson, "The gender gap in early career transitions in the life sciences," *Res. Policy*, vol. 47, no. 6, pp. 1007–1017, 2018.

[55] F. Lupi et al., "Toward a sustainable educational engineer archetype through industry 4.0," *Comput. Ind.*, vol. 134, 2022, Art. no. 103543.

[56] F. Macarie and O. Moldovan, "Gender discrimination in management: Theoretical and empirical perspectives," *Transylvanian Rev. Administ. Sci.*, vol. 35E, pp. 153–172, 2012.

[57] M. F. Manesh, M. M. Pellegrini, G. Marzi, and M. Dabic, "Knowledge management in the Fourth Industrial Revolution: Mapping the literature and scoping future avenues," *IEEE Trans. Eng. Manage.*, vol. 68, no. 1, pp. 289–300, Feb. 2021.

[58] M. J. Martinko, P. Harvey, and S. C. Douglas, "The role, function, and contribution of attribution theory to leadership: A review," *Leadership Quart.*, vol. 18, no. 6, pp. 561–585, 2007.

[59] V. Masterson, *Fewer Women CEOs Have Been Appointed Since the Start of the COVID-19 Crisis - Here's Why*, Cologny, Switzerland: World Economic Forum, 2020. Accessed: Jan. 7, 2020, [Online]. Available: https://www.weforum.org/agenda/2020/12/fewer-women-ceos-covid-gender-gap/

[60] V. W. A. Mbarika, F. C. Payton, L. Kvasny, and A. Amadi, "IT education and workforce participation: A new era for women in Kenya?," *Inf. Soc.*, vol. 23, no. 1, pp. 1–18, 2007.

[61] N. McBride and S. Liyala, "Memoirs from Bukhalalire: A poetic inquiry into the lived experience of M-PESA mobile money usage in rural Kenya," *Eur. J. Inf. Syst.*, vol. 32, no. 2, pp. 173–194, 2023.

[62] Y. Meng, "Collaboration patterns and patenting: Exploring gender distinctions," *Res. Policy*, vol. 45, no. 1, pp. 56–67, 2016.

[63] K. Miller and D. J. Vagins, *The Simple Truth About the Gender Pay Gap*. Boston, MA, USA: Amer. Assoc. Univ. Women, 2018.

[64] S. Morris, E. Barnas, D. LaFrenier, and M. Reich. *The Handbook of Journal Publishing*. Cambridge, U.K.: Cambridge Univ. Press, 2012.

[65] J. L. Mueller et al., "Using human-centered design to connect engineering concepts to sustainable development goals," *Adv. Eng. Educ.*, vol. 8, no. 2, pp. 2–24, 2020.

[66] I. Neokosmidis, N. Avaritsiotis, and Z. Ventoura, "Modeling gender evolution and gap in science and technology using ecological dynamics," *Expert Syst. Appl.*, vol. 40, no. 9, pp. 3481–3490, 2013.

[67] M. Niederle, C. Segal, and L. Vesterlund, "How costly is diversity? Affirmative action in light of gender differences in competitiveness," *Manage. Sci.*, vol. 59, no. 1, pp. 1–16, 2013.

[68] A. North and J. Noyes, "Gender influences on children's computer attitudes and cognitions," *Comput. Hum. Behav.*, vol. 18, no. 2, pp. 135–150, 2002.

[69] I. Novo-Corti, L. Varela-Candamio, and M. T. García-Álvarez, "Breaking the walls of social exclusion of women rural by means of ICTs: The case of "digital divides" in Galician," *Comput. Hum. Behav.*, vol. 30, pp. 497–507, 2014.

[70] C. O'Connell and M. McKinnon, "Perceptions of barriers to career progression for academic women in STEM," *Societies*, vol. 11, no. 2, 2021, Art. no. 27.

[71] M. F. Özbilgin and D. Woodward, "'Belonging'and 'otherness': Sex equality in banking in Turkey and Britain," *Gender, Work Org.*, vol. 11, no. 6, pp. 668–688, 2004.

[72] V. Ratten, M. M. Pellegrini, M. F. Manesh, and M. Dabic, "Trends and changes in Thunderbird International Business Review Journal: A bibliometric review," *Thunderbird Int. Bus. Rev.*, vol. 62, pp. 1–12, 2020, doi: 10.1002/tie.22124.

[73] K. Roy, D. G. Smith, and W. B. Johnson, "Gender equity is not zero sum," *Harvard Bus. Rev.*, 2020. Accessed: Jan. 7, 2020, [Online]. Available: https://hbr.org/2020/12/gender-equity-is-not-zero-sum

[74] M. Samdanis and M. Özbilgin, "The duality of an atypical leader in diversity management: The legitimization and delegitimization of diversity beliefs in organizations," *Int. J. Manage. Rev.*, vol. 22, no. 2, pp. 101–119, 2020.

[75] A. Samek, "Gender differences in job entry decisions: A university-wide field experiment," *Manage. Sci.*, vol. 65, no. 7, pp. 3272–3281, 2019, doi: 10.1287/mnsc.2018.3107.

[76] C. Shen, R. Ratan, Y. D. Cai, and A. Leavitt, "Do men advance faster than women? Debunking the gender performance gap in two massively multiplayer online games," *J. Comput.-Mediated Commun.*, vol. 21, no. 4, pp. 312–329, 2016.

[77] S. S. Silbey, "Why do so many women who study engineering leave the field?," *Harvard Bus. Rev.*, 2016. Accessed: Jan. 7, 2020, [Online]. Available: https://hbr.org/2016/08/why-do-so-many-women-who-study-engineering-leave-the-field

[78] P. E. Stephan and A. El-Ganainy, "The entrepreneurial puzzle: Explaining the gender gap," *J. Technol. Transfer*, vol. 32, pp. 475–487, 2007.

[79] A. D. Sterling and R. M. Fernandez, "Once in the door: Gender, tryouts, and the initial salaries of managers," *Manage. Sci.*, vol. 64, no. 11, pp. 5444–5460, 2018.

[80] H. Stoeger, M. Hopp, and A. Ziegler, "Online mentoring as an extracurricular measure to encourage talented girls in STEM (science, technology, engineering, and mathematics): An empirical study of one-on-one versus group mentoring," *Gifted Child Quart.*, vol. 61, no. 3, pp. 239–249, 2017.

[81] M. Sutter and D. Glätzle-Rützler, "Gender differences in the willingness to compete emerge early in life and persist," *Manage. Sci.*, vol. 61, no. 10, pp. 2339–2354, 2015.

[82] J. Syed and R. Kramar, "What is the Australian model for managing cultural diversity?," *Personnel Rev.*, vol. 39, no. 1, pp. 96–115, 2010.

[83] J. Syed and M. Özbilgin, *Managing Diversity and Inclusion: An international Perspective*. Newbury Park, CA, USA: Sage, 2019.

[84] M. I. Tazo, A. Boyano, U. Fernandez-Gámiz, and A. Calleja-Ochoa, "The gender perspective of professional competencies in industrial engineering studies," *Sustainability*, vol. 12, no. 7, 2020, Art. no. 2945.

[85] "Claudia Goldin wins the Nobel prize in economics," The Economist, 2023. [Online]. Available: https://www.economist.com/finance-and-economics/2023/10/09/claudia-goldin-wins-the-nobel-prize-in-economics
[86] H. Tokunaga and T. Graham, "Career progression in a fortune 500 company: Examination of the "glass ceiling," *IEEE Trans. Eng. Manage.*, vol. 43, no. 3, pp. 262–272, Aug. 1996.
[87] D. Tranfield, D. Denyer, and P. Smart, "Towards a methodology for developing evidence-informed management knowledge by means of systematic review," *Brit. J. Manage.*, vol. 14, no. 3, pp. 207–222, 2003.
[88] G. E. Truman and J. J. Baroudi, "Gender differences in the information systems managerial ranks: An assessment of potential discriminatory practices," *MIS Quart., Manage. Inf. Syst.*, vol. 18, no. 2, pp. 129–141, 1994.
[89] UN, "United Nations. Entity for Gender Equality and the Empowerment of Women concepts and definitions," 2001. Accessed: Oct. 13, 2023. [Online]. Available: https://www.un.org/womenwatch/osagi/conceptsandefinitions.htm
[90] UN, "United Nations Sustainable Development goals to kick in New year," 2015. Accessed: Oct. 2, 2022, [Online]. Available: https://www.un.org/sustainabledevelopment/blog/2015/12/sustainable-development-goals-kick-off-with-start-of-new-year
[91] UN, "United Nations, Sustainability," 2021. Accessed: Oct. 2, 2021, [Online]. Available: https://www.un.org/en/academic-impact/sustainability
[92] M. R. Vicente and A. Novo, "An empirical analysis of e-participation. The role of social networks and e-government over citizens' online engagement," *Government Inf. Quart.*, vol. 31, no. 3, pp. 379–387, 2014.
[93] C. Walters, G. G. Mehl, P. Piraino, J. D. Jansen, and S. Kriger, "The impact of the pandemic-enforced lockdown on the scholarly productivity of women academics in South Africa," *Res. Policy*, vol. 51, no. 1, 2022, Art. no. 104403.
[94] X. Wang, L. Wu, and L. M. Hitt, "Social Media alleviates venture capital funding inequality for women and less connected entrepreneurs," *Manage. Sci.*, pp. 1–20, 2023. [Online]. Available: https://doi.org/10.1287/mnsc.2023.4728
[95] H. P. Winchester and L. Browning, "Gender equality in academia: A critical reflection," *J. Higher Educ. Policy Manage.*, vol. 37, no. 3, pp. 269–281, 2015.
[96] World Economic Forum., "Accelerating gender parity in the Fourth Industrial Revolution: An agenda for leaders to shape the future of education, gender and work," 2017. Accessed: Jan. 7, 2020, [Online]. Available: http://www3.weforum.org/docs/WEF_EGW_White_Paper_Gender_Parity_4IR.pdf
[97] A. Xiong, J. Tao, H. Li, and H. Westlund, "Will female managers support gender equality? The study of "Queen Bee" syndrome in China," *Asian J. Social. Psychol.*, vol. 25, pp. 544–555, 2022.
[98] X. Zheng and H. Lu, "Does ICT change household decision-making power of the left-behind women? A case from China," *Technological Forecasting Social Change*, vol. 166, 2021, Art. no. 120604.
[99] A. Gilarek, "Marginalization of "the Other": Gender discrimination in dystopian visions by feminist science fiction authors text matters," *J. Literature, Theory Culture*, vol. 2, 2012.
[100] N. Levit, *The Gender Line: Men, Women, and the Law*. NYU Press, vol. 78, 1998.
[101] N. Ellemers, "Gender stereotypes," *Annu. Rev. Psychol.*, vol. 69, pp. 275–298, 2018.
[102] T. Dietz, L. Kalof, and P. C. Stern, "Gender, values, and environmentalism," *Social Sci.*, vol. 83, no. 1, pp. 353–364, Quarterly, 2002.
[103] R. Campbell–Montalvo et al., "How stereotypes and relationships influence women and underrepresented minority students' fit in engineering," *J. Res. Sci. Teach.*, vol. 59, no. 4, pp. 656–692, 2022.
[104] M. F. Manesh, M. M. Pellegrini, G. Marzi, and M. Dabic, "Knowledge management in the fourth industrial revolution: Mapping the literature and scoping future avenues," *IEEE Trans. Eng. Manage.*, vol. 68, no. 1, pp. 289–300, 2020.
[105] D. E. Bowen and C. Ostroff, "Understanding HRM–firm performance linkages: The role of the "strength" of the HRM system," *Acad. Managementc Rev.*, vol. 29, no. 2, pp. 203–221, 2004.
[106] A. Panteli et al., "The status of women in the UK IT industry: an empirical study," *Eur. J. Inf. Syst.*, vol. 8, pp. 170–182, 1999. [Online]. Available: https://doi.org/10.1057/palgrave.ejis.3000326
[107] N. Panteli, J. Stack, and H. Ramsey, "Gendered patterns in computing work in the late 1990s," *New Technol., Work Employment*, vol. 16, no. 1, pp. 3–17, 2001.
[108] M. W. Nielsen, "Scandinavian approaches to gender equality in academia: a comparative study," *Scand. J. Educ. Res.*, vol. 61, no. 3, pp. 295–318, 2017.
[109] M. Niederle and L. Vesterlund, "Do women shy away from competition? Do men compete too much?," *Quart. J. Econ.*, vol. 122, no. 3, pp. 1067–1101, 2007.

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