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Perspective

Lessons learned from the underrepresentation of women in STEM: AI-enabled solutions and more

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The participation of women science, technology, engineering and mathematics (STEM) and energy fields is essential in advancing knowledge, securing economic growth, promoting prosperity and contributing to the well-being of societies. Although the number of women involved in STEM fields has recently witnessed an increase in comparison to their natural counterparts, the “leaky pipeline” metaphor still applies. A greater number of women “leak out” and leave the educational and professional pipelines at every stage of their lives, transitioning from school to university to their careers, than men [1]. The epitome of gender differences in the fields of STEM and energy industry can be captured by the disparities in representation of women in publications, salaries, senior rankings, annual productivity and resources allocation [2]. In 2018, in the United States, women accounted for about a third of full professors (34%), showing that they significantly hold fewer senior positions compared to men [3]. Similarly, in 28 countries of the European Union in 2016, women appointed to senior ranks in academia accounted for about 24%, not only that but also, in the United Kingdom in 2019, it was reported that women in academia earned about 15%, on average less than their counterparts [3].

The prominent dearth of women in the fields of STEM and energy sectors is driven by salient axes of discrimination including gender, race and class, socio-cultural factors, institutional patterns of bias as well as underrepresentation cultural norms that underly societal principles; consequently, many women do not persist in their careers in STEM neither do they advance to senior rank positions [4]. When such factors add up together, they can perpetuate a hostile atmosphere for women, leading to their exclusion from the scientific community [5].

From one point of view, disparities in women's participation leading to their underrepresentation in fields of STEM can be because of the influence of male-dominated environments, which have planted the notion that STEM fields are masculine, as this context of masculinity is “produced, reproduced, negotiated and contested” early on since school stages [6]. The gender-stereotypical images of such fields were further fostered in certain areas than in others, producing a larger gap in women inclusion in STEM. For instance, engineering has become connotated with images of “dirty hands” and “heavy and tough”, while the field of computer science is rather perceived as “geeky” [5].

Another point of view argues that underrepresentation of women in STEM and energy industries would be due to inherent differences in the evolutionary psychology of men and women [6]. Men have more developed mechanical, cognitive and spatial visualization skills, whereas women have more advanced verbal abilities and motor coordination skills. Even so, these gender-based mental rotation abilities can be easily compensated for by providing women with the necessary training, trust and support. Collectively, these stereotypical attitudes and expectations have mounted to characterize engineering and technology disciplines to be resilient to efforts of gender inclusion and diversity (I&D), compared to other fields in STEM.

In the Middle East, tenacious gender stereotypes have caused a skewed gender ratio in STEM, which served as fertile arenas for women to fall behind their male peers in professional achievement in certain fields, like engineering and energy industries. However, a recent study by Darwish, Alzayed and Ahmed [7] showed that the role of Arab women in STEM fields has become more evident and their contributions to the scientific community have become inevitably considerable. According to Minhas [8], social motivations have allowed women to unshackle from their historical conventional roles and to annex themselves more to the STEM community. Led by the strong national movements, which promote female empowerment, along with the openness and connectedness with the rest of the globalized world; awareness of the role of women in modern civilizations drastically increased.

Yet, with all the current efforts of women to become integrated into the scientific body, they remain insufficient as women underrepresentation is still a defining characteristic of modern professional contexts. The current circumstances due to the COVID-19 situation rather widened the gap and increased the gender representation heterogeneity in energy and STEM disciplines. A recent survey showed that due to the pandemic's countermeasures, there is a noticeable disproportionate decline in time devoted to research by females, subject to differential effects of gender, as shown in Fig. 1 [9]. The researchers concluded that the females’ productivity slowed down due to the burden of taking care

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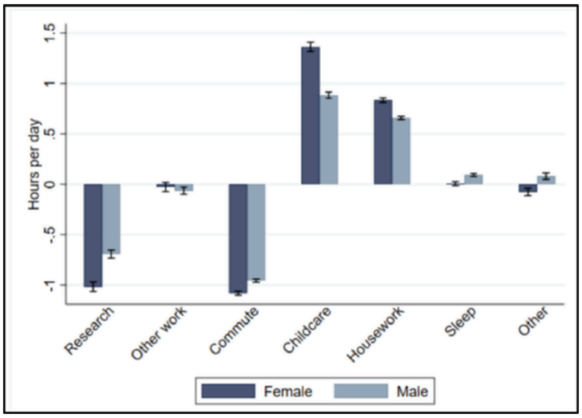

Fig. 1. The change in hours spent by both genders on different chores, during the COVID-19 pandemic [9].

of children, day-care closures, and increased housework because of working from home.

Moreover, Squazzoni et al. [10] reported that the effects of the pandemic on women productivity in research were even evident in the deficit in number of manuscripts submitted by females to Elsevier journals in the year 2020. A preliminary analysis of the number of preprints published on arXiv repository, which is an open-access archive that hosts electronic preprints pertaining to STEM fields, showed that the percentage increase of publications by male authors exceeded that of female authors, before and after the COVID-19 outbreak in March 2020 [11]. This analysis, shown in Fig. 2, provides a fair prediction of the increasing gap in gender bias in STEM, inflicted by the inherent imbalances in common care-giving and domestic labour regimes which were further augmented during the pandemic.

According to Gallego et al. [12], in the corporate world, about half of the university graduates are women, of which 36% hold STEM degrees. Women account for 38% of the total labour force, 25% of which are in STEM fields, where only 5% hold CEO positions. A survey conducted by the Global Women Network for the Energy Transition (GWNET) in 2020 reported that women make up only 22% and 32% of the total workforce in traditional and renewable energy sectors, respectively [13]. So, acknowledging the nested levels of women I&D in STEM and energy, it is necessary for worldwide actions to take place to address these disparities in gender composition and to promote intersectional equality. Recognizing the consequences of gender demographics within the STEM fields is a necessity to develop practical solutions that would dissolve such inequities. Artificial Intelligence (AI) can be utilized for the social good, to mitigate the implicit biases encountered in STEM and energy industries, underlined by gender disproportionated representation. Unlike humans, AI can be designed with algorithmic features that lack the inherited societal biases which inhibit I&D in various frameworks [14]. AI-mediated targeted interventions can start with the simple actions of institutions assessment of gender inequities in recruitment, retention and advancement, whether focused by discipline or career stage. AI-enabled solutions like analysis tools can be used in any context (i.e. comparative analysis of annual productivity of male and female professors in an engineering college) to measure, evaluate and report adverse impact measures of gender discrimination. This would help authoritative figures undertake serious actions to moderate the differences at the given workplace, academic or research context [14]. For example, scientific publishing companies can utilize AI algorithms to analyse male and female authors contributions, quantify the reach to both genders and to assess the extent of I&D in their technical cultures.

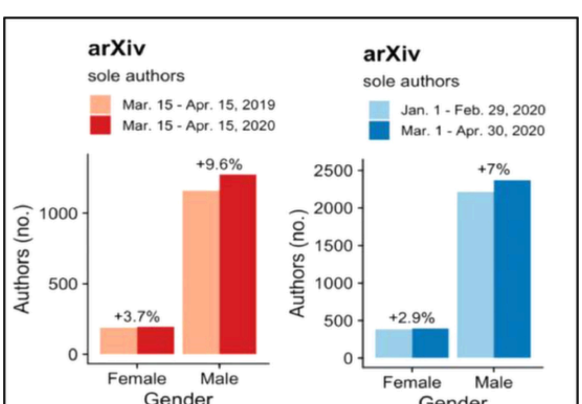

Fig. 2. The percentage increase in preprint publications on arXiv repository, by male and female authors, before and after the onset of COVID-19 [11].

Another way by which AI can contribute to improving I&D of women in energy and STEM is by providing equal jobs, research or studies opportunities, solely depending on the skills of the person rather than indicators which could predispose judgments like gender and race. AI can be deployed to match a pool of applicants to a certain vacancy by abiding to a neutral selection methodology, depending on the applicants' experiences and abilities, irrespective of any of their personal attributes. Unilever reported that following the introduction of "robo-interviews" conducted by chatbots to interview candidates instead of HR personnel, as part of its AI-based digital hiring strategy, they increased workplace diversity by more than 15% [12]. Thus, the use of AI-enabled solutions can greatly eliminate prejudiced preferences associated with humans' choices.

Another AI tool developed by Joonko [15] can be used to recommend and optimize management tools for leaders to minimize unconscious biases which happen on day-to-day basis in the workplace. Cumulatively, such technology would create a more neutral environment that would provide women with equal chances to contribute and professionally develop [15]. Not only that but also, since women usually carry the larger burden of house and family care, AI can be integrated to lighten the load, indirectly sparing women more time to spend on their research and careers. As discussed previously about the COVID-19 countermeasures which severely affected women's progress in research, AI conversational technology, like Alexa for example, can reduce the stress of balancing homecare and work obligations. Fig. 3 suggests other technological interventions that can be employed to promote gender I&D.

Nevertheless, machine learning (ML) is a feature that allows AI systems to develop themselves, permitting them to implicitly learn from the data they collect and develop capacities to understand and analyse complex contexts without explicit human programming [16]. Therefore, chances of AI perpetuating harmful partialities resulting from interactions with humans and ML exist, where such automated systems could develop to reinforce the existing gender stereotypes and discrimi-

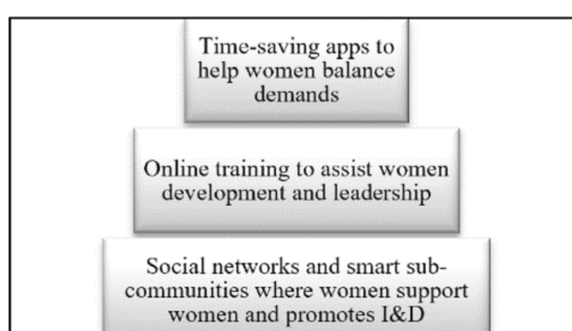

Fig. 3. Suggested technological interventions to promote gender I&D in STEM [17].

natory societal norms. However, with reasonable measures and careful design of the technology, such biases can be avoided. These concerns can be controlled if the right datasets and algorithms are employed and routinely checked for data biases, then, the models' features can be adjusted and corrected as necessary. Hence why recently companies and engineers spend many efforts in designing tools which would detect biases in AI datasets and help maintain neutrality.

To serve such correction purposes, Burnett developed "GenderMag", which is a "gender inclusiveness magnifier" tool for auditing AI software for gender biases in their user interfaces [16]. Other tools to ensure fairness and accountability of AI systems for the purposes of endorsing gender I&D include testing them with white-box ML interpretable models, performing counter-factual analyses and creating model cards [16]. Moreover, governments play a vital role in AI regulation to prevent biases. For instance, the US, UK, France and other countries have passed legislations which entitle tech companies to audit their AI technologies for biases and fairness, and accordingly, take corrective measures [15].

Aside from the abovementioned contemporary approaches and given the difficulty of predicting which interventions serve best in which institutional contexts, it is recommended to incorporate strategies which promote intersectionality and involve majority of the marginalized population of women in STEM fields. Such approaches should be data-driven, based on dissecting the obstacles and smartly devising solutions and plans that would be deemed successful in approaching a unique challenge found in a given underrepresentation context [5]. Sub-communities where women support women to communicate, represent and prosper should be invested in and resourced. A noteworthy example is the STEM Equity Achievement (SEA) change initiative, which was established by the American Association for the Advancement of Science (AAAS) in 2018 [17]. This initiative provides systematic mechanisms that institutions can adopt and integrate, in order to create diverse, inclusive and equitable environments that ensure women's safety, empowerment and advancement. The SEA change supports institutional transformation that aims at achieving a balanced demographic distribution that would allow women to have equal opportunities and advancement chances, especially in the academic and research domains of STEM.

Fig. 4 [17] shows the three pillars of the SEA Change initiative, which comprise a supportive community, an institute and a series of awards. Basically, this act hosts a community which brings together several allied organizations and institutions that share the goal of promoting I&D. Also, it is a platform that provides access to a wide range of useful resources on the notions of I&D, such as courses, training programs and targeted initiative plans. Lastly, the SEA Change initiative recognizes the best institutions which present promising practices for conquering challenging barriers to progression that affect women and provide positive incentives in the forms of departmental and institutional awards.

The SEA Change effort was primarily inspired by the English Athena SWAN (Scientific Women's Academic Network) Charter, launched in 2005 [18]. The Athena SWAN Charter originally focused on encouraging and recognizing efforts dedicated to closing gaps pertaining to gender equality and advancing women's journeys through STEM career milestones. In 2015, the charter expanded to become a global framework that supports gender equality and representation in research and

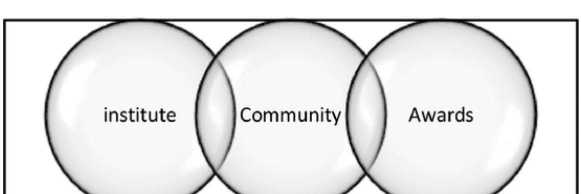

Fig. 4. The three pillars of the SEA Change initiative [17].

education, in a much broader context, considering fields of arts, humanities, social sciences, business and law (AHSSBL) along with the primary STEM field. To this end, the charter commits to providing institutions with a progressive framework to guide them towards addressing underrepresentation issues of women in STEM, the highly variable disparities in the rates of women contribution and retention in STEM, as well as mainstreaming sustainable cultural changes that would allow women to advance in their career development and progression. Other initiatives focusing on women inclusion and engagement in the sustainable energy sector include the GWNET's empowerment campaigns, the women in energy committee association, and engagement motions promoting I&D, supported by the International Renewable Energy Agency (IRENA) [19,20].

In conclusion, it is a must for the world to realize that academia, research, sciences, technologies, and engineering cannot reach their full potentials unless all talents can contribute and be represented equally. As more awareness has been risen to women underrepresentation in STEM and the essentiality of dissolving the skewed distribution, efforts and initiatives are emerging to attain that demographic balance. Of particular interest, the application of AI-enabled solutions to promote gender equality and fair inclusion are gaining augmented attention. With the pitfalls known and acknowledged, efforts are being made to improve this technology, in collective hopes that it can mitigate the issue and minimize the gap.

Declaration of Competing Interest

The author declares that he has no known competing financial inter- ests or personal relationships that could have appeared to influence the work reported in this paper.

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