Women in Engineering Education: Five Strategies to Promote Women in Engineering Education

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Abstract **—The article explores diverse approaches to advancing women in engineering education, a crucial topic given the pervasive gender imbalance in this domain. The review emphasizes the implementation of educational modifications in the field of engineering with the objective of increasing its attractiveness to female students. These modifications include the incorporation of practical applications and interdisciplinary topics, as well as the utilization of active learning methodologies. The present article suggests the potential of the Maker Movement to promote gender equality in engineering education by highlighting its experiential and innovative pedagogical approach. This study emphasizes the importance of cultivating educational environments that are inclusive and supportive, as they are crucial in advancing gender diversity in engineering education. These learning environments promote participation and facilitate success, especially for female students, by fostering a sense of belonging, addressing unconscious bias, and establishing a hospitable physical setting. Additionally, the significance of introducing engineering concepts at an early stage of K-12 education is presented, arguing that this exposure has the potential to spark the interest of female students, challenge existing stereotypes, and influence their career goals. Finally, this mini review highlights the impact that mentorship can have on encouraging women to pursue careers in engineering. The provision of personalized guidance, assistance in navigating challenges, and demonstration of successful behaviors and attitudes by mentors and role models can greatly enhance the pursuit and persistence of women in engineering careers. In summary, this review article provides strategies for advancing women in engineering education, highlighting the need for a multifaceted approach in order to attain a more diverse and inclusive engineering labor force.**

Keywords—STEM, Engineering Education, Engineering Curriculum, Engineering Pedagogy, Women.

I. Introduction

Science, technology, engineering, and mathematics or commonly abbreviated as STEM has gained significant interest globally especially in the United States. It has been extensively employed in conversations concerning technology advancement and educational reform, as evidenced by scholarly works [1-4]. In light of the significant impact that technology development has on both individuals' daily lives and a nation's competitive edge, an increasing number of countries have augmented their investments in STEM-related sectors, including engineering and information technology [3, 5, 6]. The development and cultivation of talents for industries necessitate the provision of STEM education.

The efficacy of STEM education in countries that have recently initiated its development, such as Hong Kong, remains insufficiently researched despite the extensive studies conducted on the subject in the United States [7]. In addition, STEM disciplines and the ICT industry are commonly perceived as domains that exhibit masculine characteristics. The phenomenon of gender stereotyping is pervasive within the STEM fields and educational institutions, leading to a decrease in girls' self-assurance and enthusiasm for information and communication technology (ICT), as well as diverting them from pursuing ICT education and professional paths.

It is interesting to note that curricular and instructional changes play a significant part in the process of making engineering education more appealing to female students. Real-world applications, multidisciplinary topics, active learning methodologies, and varied role models are all things that can help bring more women into engineering and keep them there. However, in order to effectively build a gender-inclusive engineering education system, these improvements need to be implemented carefully and supported by broader institutional changes. This initiative is not only about establishing diversity; rather, it is about energizing the field of engineering with varied viewpoints and ideas from a variety of people. After all, a workforce that is more varied in the engineering field is one that is more innovative and effective.

II. Strategies for Promoting Women in Engineering Education

The five strategies to promote women in engineering education is outlined in Fig. 1.

A. Curriculum and pedagogical reforms to make engineering more appealing to women

Developing an educational system for engineering that is inclusive of both genders is challenging [8, 9]. It is, therefore, important to change many levels from the curricula, the pedagogy, the classroom settings to institution policies. This article intends to explore into the curriculum and pedagogical

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innovations that can make engineering more interesting to women and, as a result, build a more varied and inclusive community within the engineering field.

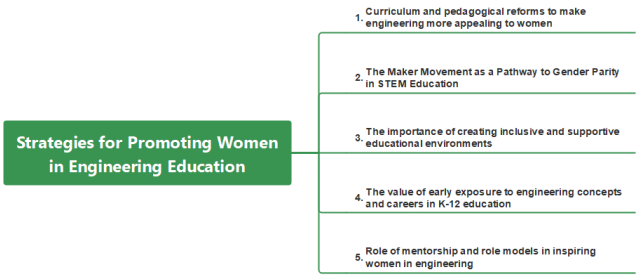

Fig. 1. Five approaches in promoting female students to participate in engineering education

It has been known for a long time that the present standard curriculum for engineering, which is defined by a theoretical and lecture-based approach, is a barrier for the involvement of female students. This one-size-fits-all approach does not respond to the various preferences that learners have and fails to highlight the societal and practical ramifications of engineering, both of which are particularly appealing to women, according to studies.

The reform of the curriculum should start with demonstrating the applicability of engineering to problems that are actually occurring in the world and in society as a whole. However, the societal impact that engineering may have and its potential for bringing about constructive change are frequently not highlighted enough in educational programs. We can highlight the direct impact that engineering has on societal challenges by reorienting the curriculum towards problem-solving and real-world applications.

In addition, incorporating multidisciplinary topics into the educational experience of engineering students may encourage more women to enter the profession [10, 11]. Engineering may be utilized as a tool to tackle complicated problems in a variety of fields, and students who take courses that bridge disciplinary lines, such as bioengineering and environmental engineering, learn how this can be accomplished. Reforming the educational system is also very crucial. In engineering, the traditional teaching technique, which is based on lectures, does not lend itself well to engaging students or encouraging active learning. Active learning practices, such as problem-based learning, collaborative projects, and hands-on experiments, can be implemented to promote engagement and comprehension, particularly among women.

Maker movement is one of the examples [12-14]. Students are given the opportunity to investigate, experiment, and create as a result of the incorporation of maker education into the engineering curriculum. These are activities that promote a deeper understanding of the topic and motivate students to get enthusiastic about it. The maker movement has proven to be effective in attracting women to careers in engineering and other STEM professions by combining creative expression with real-world application.

The use of cooperative learning and group projects in the classroom can provide the environment in the classroom more welcoming to all students. Women, who typically place a higher priority on community and collaboration, may find that these different learning modalities are more appealing. The creation of a sense of community through participation in group activities can also be beneficial in retaining women in engineering degree programs.

Despite what has been said above, the success of curriculum and pedagogical reform depends on its being carried out in the correct manner. To successfully execute these reforms, educators need to receive appropriate training, and educational institutions need to demonstrate their support for these initiatives. It is necessary to confront and question implicit biases, prejudices, and gendered expectations. Overall, the incorporation of many types of role models into the educational experience can be transformative. It is possible to inspire women to pursue a career in engineering by challenging the traditional picture of an engineer by presenting case studies, examples, or guest lectures given by successful women engineers.

B. The Maker Movement as a Pathway to Gender Parity in STEM Education

Gender differences in education has received significant attention [15]. Despite recent efforts to foster inclusive engineering and computing cultures, the majority of STEM disciplines are still dominated by men and have an significant gender gap, particularly in the United States [16, 17]. Promisingly, the broader maker movement taking place in K-16 settings has shown notable exceptions with engaging young girls in STEM, including accounts of circuitry learning [18-22] and other core STEM disciplinary concepts and practices [23-25].

A prominent study of females in maker and STEM activities demonstrates that changes in the materials associated with STEM can influence how and by whom STEM learning is practiced, resulting in better learning outcomes [21]. The emphasis of the studies is on initiating women's participation in STEM-related activities through creative projects [26, 27].

Gender parity in the STEM fields, has been a recurrent topic of discussion on a global scale. In spite of significant efforts by educational reform movements and initiatives to promote gender inclusivity within engineering and computing cultures, the male-dominated STEM environment persists, especially in the United States [2, 3]. There is, however, a promising paradigm shift, with the emergence of the broader maker movement in K-16 settings demonstrating remarkable progress in engaging girls in STEM fields, including studies in circuitry learning [4-8] and other foundational STEM disciplinary concepts and practices [9-11].

It is noteworthy that project-based learning, a prominent constituent of the maker movement, cultivates an atmosphere that enables learners to generate their own innovative resolutions to authentic problems. In this context, the encouragement of women's involvement in creative pursuits yields a dual advantage. Initially, it facilitates a more profound comprehension of STEM principles by affording pupils with practical involvement. Secondly, through the cultivation of an inclusive environment that facilitates the active participation and contribution of girls, these initiatives serve to eliminate the barriers that often discourage girls from pursuing STEM fields.

The efficacy of this movement is contingent upon its grassroots execution. It is necessary that educators receive sufficient training to effectively facilitate maker education, while maintaining a balance between imparting fundamental

curriculum material and encouraging student-led initiatives. Furthermore, it is imperative for academic institutions to establish conducive settings that promote trial and error and acknowledge setbacks as an essential component of the educational journey.

Furthermore, the significance of the functions performed by parents and society should not be underestimated. Promoting the involvement of young girls in STEM fields within the household setting has the potential to significantly enhance their self-assurance and drive. The utilization of mass media and popular culture can potentially exert a substantial influence in the alteration of societal perspectives regarding women in STEM fields.

Ultimately, the provision of institutional and policy support is crucial. To effectively revolutionize STEM education and address gender disparities, it is imperative that educational policies prioritize and advocate for inclusive pedagogical approaches, such as those that are characteristic of the maker movement. The implementation of such policies has the potential to serve as a catalyst for systemic transformation, thereby prompting other institutions to emulate a comparable approach.

The maker movement presents a promising opportunity for attaining gender equality in STEM fields, which may appear to be a challenging undertaking. The statement underscores the significance of innovative and experiential education in rendering STEM fields attractive to students of all genders. Despite being in its early stages, this transformative movement has the capacity to initiate a fundamental change in STEM education, leading to a period of heightened diversity and inclusivity.

C. The importance of creating inclusive and supportive educational environments

The creation of an inclusive environment fosters the engagement of all students [28], regardless of their demographic characteristics, and also nurtures a setting where a variety of perspectives can flourish, resulting in effective solutions and originality. Throughout history, the field of engineering has been predominantly male-dominated [29], and this pattern has endured in academic environments, potentially engendering a climate in which female students may experience a sense of isolation or diminished worth. The outcome is a notable disparity between genders in the field of engineering education, which consequently extends to the engineering occupation.

It is imperative to deliberately foster an educational environment that is all-encompassing and encouraging of every student, especially those who have been traditionally marginalized, such as females. This entails surpassing the mere augmentation of female student enrollment in engineering courses. Facilitating a sense of belonging is a viable approach to establishing such an environment. The experience of isolation or a sense of not belonging can be influential factors contributing to increased rates of attrition among female students pursuing engineering degrees. The implementation of mentorship initiatives, establishment of supportive networks, and promotion of women's participation in group projects and team activities can foster a sense of inclusivity and belonging.

It is also to provide teachers with training that enables them to comprehend and tackle unconscious bias and gender stereotypes. Moreover, the tangible setting of the classroom and the instructional materials employed can also impact individuals' perceptions of inclusiveness [30]. Incorporating pertinent real-life illustrations, utilizing gender-neutral terminology in instructional resources, and establishing an inviting physical setting can collectively foster a more comprehensive milieu.

An educational environment that is supportive is characterized by the recognition and promotion of the distinctive contributions made by each student. The implementation of supportive pedagogical approaches, such as the provision of constructive feedback, acknowledgement of exertion, and affirmation of the ideas presented by female students, has the potential to enhance self-assurance and foster perseverance within the female population studying engineering. In addition to classroom instruction, academic support may be provided through avenues such as academic advising and counseling, supplementary learning resources, and assistance with career planning and internships.

It is worth noting that the establishment of an inclusive and supportive educational milieu is contingent upon the broader institutional culture and policies. It is imperative for institutions of higher education to prioritize gender balance in their faculty appointments, promote female leadership, and implement strict measures against discriminatory and harassing behaviors. Academic institutions can exhibit their support for women in engineering by organizing events or clubs that cater to this demographic, offering scholarships or awards that are exclusively available to female students, or conducting outreach programs that aim to inspire more young women to pursue a career in engineering.

The factors mentioned above promote a feeling of inclusion, stimulate engagement, and furnish assistance for achievement. Although the establishment of such an atmosphere necessitates deliberate endeavor and structural modification, the advantages are numerous.

D. The value of early exposure to engineering concepts and careers in K-12 education

The imperative to achieve gender equality in domains such as engineering necessitates an early initiation of efforts well before the commencement of tertiary education. The early introduction of engineering concepts and careers, particularly within K-12 education, is considered a highly promising strategy for mitigating the gender gap in these fields [31]. The initial introduction to engineering has the potential to significantly influence one's outlook, mindset, and professional ambitions, particularly for females, thereby establishing the foundation for a more equitable representation of genders within the engineering industry.

Initially, early exposure to engineering concepts and professions has the potential to challenge and disrupt preconceived notions and stereotypes regarding the discipline [32]. Engineering is frequently depicted in mainstream media as a discipline that is dominated by men, characterized by a strong emphasis on technical proficiency, and perceived as lacking in creativity and social significance. The integration of engineering concepts into K-12 education can offer students a more precise and attractive comprehension of the nature of engineering. It is possible to demonstrate to individuals that engineering encompasses not only technical expertise, but also ingenuity, the ability to address challenges, and the capacity to effect beneficial change within society.

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Providing girls with early exposure to engineering can contribute to demystifying the field. By presenting engineering concepts in a captivating and relevant manner, it is possible to stimulate the interest of young girls in engineering and encourage them to consider it as a feasible and appealing career option. Hands-on projects that provide students with the opportunity to design and construct their own creations can render engineering palpable and stimulating. These projects have the potential to exhibit the pragmatic implementations of engineering, thereby imparting knowledge to students regarding the utilization of engineering principles for resolving real-life predicaments.

Facilitating opportunities for female engineers to speak in educational settings or arranging visits to engineering firms can provide students with exposure to accomplished women in the field of engineering. These encounters have the potential to disrupt the conventional perception of engineers and motivate young women to contemplate engineering as a viable profession.

The integration of engineering principles and professions into K-12 education necessitates a careful approach. Mere supplementation of educational material to an already saturated syllabus is insufficient. The integration of engineering education across various subjects, including science, math, arts, and social studies, is imperative to showcase its interdisciplinary nature. It is imperative that educators receive sufficient training and resources to proficiently instruct engineering principles and foster a constructive educational atmosphere that promotes inclusivity, thereby enabling all pupils, irrespective of their gender, to feel motivated to explore and acquire knowledge.

Moreover, the role of parents and guardians is crucial in molding the perceptions and attitudes of children towards various career options [33]. Facilitating dialogues between parents and guardians regarding engineering and equipping them with materials to foster their children's interest in engineering can have a substantial impact on the attitudes of girls towards engineering.

All in all, through the process of challenging stereotypes, generating interest, and presenting diverse role models, it is possible to influence the perceptions and attitudes of girls towards the field of engineering. The effective incorporation of engineering into K-12 education necessitates collaborative endeavors among educators, policymakers, parents, and the wider community. By implementing strategic planning and efficient execution, providing early exposure to engineering can potentially cultivate a more diverse and inclusive engineering workforce in the forthcoming years.

E. Role of mentorship and role models in inspiring women in engineering

The provision of mentorship and the availability of role models are crucial factors in the promotion of gender diversity within the field of engineering [32]. Mentors and role models possess the capacity to motivate and bolster the pursuit and endurance of women in engineering careers through the provision of guidance and support, as well as the demonstration of successful behaviors and attitudes.

The practice of mentorship offers a multitude of advantages specifically for women who aspire to become engineers. Mentors, typically seasoned practitioners in the domain, can furnish individualized counsel, direction, and evaluation that can prove to be priceless for female novices endeavoring to establish a vocation in engineering. Mentors can assist in navigating the obstacles of working in a male-dominated industry, offer guidance on career growth and progression, and cultivate self-assurance and efficacy in their protégés.

The presence of a mentor who possesses a comprehensive understanding of and adeptly manages the obstacles that accompany women's participation in a predominantly male domain can furnish a sense of comfort, diminish sentiments of seclusion, and augment tenacity in the field. The mentor is capable of offering pragmatic guidance pertaining to the management of work-life equilibrium, surmounting imposter syndrome, and devising tactics for achieving success. Furthermore, mentors have the potential to offer prospects for networking, professional growth, and progression in one's career. Mentors can facilitate the establishment of valuable connections, enhance visibility, and provide access to opportunities that may have been otherwise unattainable for women engineers by introducing them to professional networks.

Conversely, role models, who serve as exemplars of successful behaviors and attitudes, can be a source of great inspiration for women pursuing careers in engineering. Role models serve as exemplars of success in a given field and offer a concrete demonstration of what can be achieved. They contest gender norms and exhibit that females can achieve success in the field of engineering. Role models serve as exemplars of the potential achievements of women in the field of engineering, demonstrating that it is feasible to defeat obstacles and attain success in this domain.

Exemplars can be encountered in diverse settings, ranging from educators and scholars to corporate executives and pioneers of novel ideas. It is imperative for educational institutions and engineering companies to emphasize and commemorate accomplished female engineers as a means of furnishing young women with role models.Despite the potential impact of mentors and role models, it is important to note that they do not offer a panacea for addressing the issue of underrepresentation of women in the field of engineering. Inclusion of interventions within a comprehensive strategy that encompasses educational reforms, institutional policies, and societal changes is imperative. In addition, it is imperative that mentors and role models exhibit diversity in terms of their backgrounds, experiences, and career trajectories in order to demonstrate the various avenues through which women can achieve success in the field of engineering.

Overall, mentorship and the presence of role models have a crucial impact on motivating women in the field of engineering. The provision of support, guidance, and a visionary outlook is instrumental in augmenting the proportion of women who opt for and persevere in engineering vocations. Although there are obstacles that remain to be addressed, the existence of mentors and exemplars represents a noteworthy advancement towards achieving a positive outcome. Fig. 2 summarizes the benefits of mentorship in inspiring women in engineering.

III. CONCLUSION

To summarize, the advancement of gender diversity in engineering education necessitates a comprehensive strategy that integrates curriculum revision, inclusive pedagogical techniques, early engineering exposure, and effective role

models and mentorship. The Maker Movement exhibits potential as a means of involving young girls in STEM, and the establishment of educational settings that are supportive and inclusive is crucial in cultivating a sense of affiliation and promoting the involvement of all pupils. Furthermore, it is imperative to introduce engineering concepts at an early stage in K-12 education to confront existing stereotypes and influence future professional aspirations.

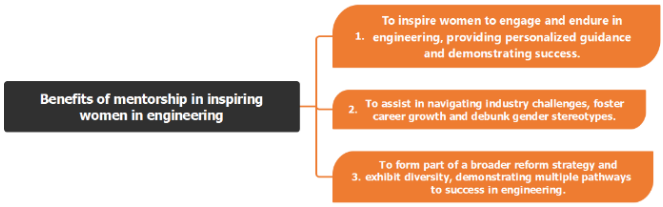

Fig. 2. Mentorship advantages to inspire women pursue career in engineering.

The existence of mentorship and role models can exert a substantial impact on women's inclination to pursue and sustain engineering professions. This underscores the importance of prominent and reachable female engineers. Rather than operating in isolation, it is advisable that these efforts be integrated into a broader, all-encompassing initiative aimed at effecting systemic transformation across all tiers of education and within the engineering field.

Despite notable advancements, attaining gender equality in engineering education and the industry as a whole remains an ongoing endeavor. Gender equality in engineering education is the responsibility of many stakeholders, including educators, policymakers, and society. This is due to the recognition of the significant benefits that diversity provides in promoting innovation, creativity, and societal influence. The complete realization of the potential of the engineering field can only be achieved under such circumstances.

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