



STEM Education and Gender Gap: Pedagogical Strategies to Promote Female Participation

Joydeb Patra 

Assistant Professor of Sociology
School of Law
Brainware University, West Bengal, India
joydebajoy@gmail.com

Abstract. Gender disparity in STEM education continues to pose a serious problem in achieving balanced development and innovation. Even with measures to address the issue, the gender gap persists owing to socio-cultural barriers, gender stereotypes, the absence of role models, and pedagogic challenges. This paper aims to investigate pedagogic strategies to enhance participation and retention rates of females in STEM education, especially within the Indian context. It assesses pedagogic strategies that can improve female enrolment and retention within STEM education. Pedagogic measures include gender-sensitive teaching methodologies, inclusive curricula, mentorship programmes, and collaborative learning. In this regard, the study analyses the importance of teachers in addressing implicit biases, creating a conducive learning atmosphere, and promoting gender parity. Moreover, the effect of exposing girls at a tender age to STEM subjects, using gender-neutral language, and integrating female scientists' achievements into the syllabus will be discussed. In conclusion, based on the available literature and case-based evidence, this paper proposes that changing the pedagogical framework could help solve the gender imbalance in STEM education. In conclusion, ensuring gender equality in STEM education is not just an issue of social justice but an essential factor for sustainability and competitiveness.

Keywords: Gender Gap, STEM Education, Inclusive Pedagogy, Female Participation, Gender-Sensitive Teaching

1. Introduction

STEM (Science, Technology, Engineering, and Mathematics) education is a distinctive characteristic of the 21st century due to the impact that the sector has on the direction of economic growth, innovations, and international competition in the context of globalisation. Nowadays, the role of science and technology in solving complex global problems, such as climate change, health-related issues, sustainable development, and the digitalisation of society, is particularly important. Thus, there is a need to invest more effort into enhancing STEM education systems in order to address emerging challenges effectively (1).

Despite the increasing significance of STEM education, however, inequality between men and women in this sphere persists in its traditional forms. According to available statistics, only approximately one-third of STEM students worldwide are females, which shows a serious imbalance that exists in terms of access to STEM disciplines, despite the long period of time that the problem has existed and various measures taken to tackle it. The situation is especially concerning in such areas as engineering, IT, and physics (2).

From the perspective of India, the case has both its merits and demerits. First, the number of females enrolling in higher education institutions has increased significantly compared to earlier times, which shows that more people have been able to avail themselves of educational opportunities in recent years (3). However, the problem is not uniform, meaning that the female population does not take up all disciplines equally. There is a high concentration of females studying in life sciences and related courses, while they are relatively underrepresented in engineering, technology, and advanced sciences.

The gender gap in STEM education is multidimensional and involves several dimensions, such as socio-cultural aspects, institutional barriers, and teaching styles. The socio-cultural aspect is crucial since the norms dictate what kind of courses individuals should pursue based on gender. In the traditional sense, men are supposed to study science-related courses, while women are meant for the caregiving professions or humanities. The stereotypes form when children are young, discouraging them from studying the subject. Additionally, family pressure and cultural norms restrict the dreams of the young girls. There are institutional practices that exist within the educational system that can contribute to gender inequalities (3). The schools or institutions themselves can perpetuate biases by means of their curriculum content, assessments, or classroom activities. The lack of female scientists and innovators in textbooks prevents students from seeing women as role models who have made significant contributions to the field. There are also tendencies for class discussions or teacher attention to be biased towards boys.

The pedagogy involved in STEM education is another critical factor in promoting gender equality or inequality. Competitive pedagogy, rote pedagogy, or individualised pedagogy has been associated with male dominance in STEM fields. On the other hand, inclusive pedagogy is designed to promote diversity by fostering collaboration, cooperation, and experiential learning, allowing female students to feel more confident. The second important reason for the presence of a gender gap is related to the absence of female role models and mentors in STEM education. As a result, young women cannot find examples of women succeeding in science and technology, which makes it more complicated for them to follow the same path.

It is crucial to note that problems in the gender balance in STEM go beyond enrolment statistics. Although women pursue education in STEM areas, there are several factors that prevent them from continuing to follow this career path further. Such issues as workplace discrimination, lack of advancement possibilities, work-life balance problems, etc., make women leave the STEM field in higher numbers than men. The phenomenon of gradual female loss is called the "leaky pipeline." The problem of inequality in STEM is rather complex; therefore, its resolution should also be multifaceted. While this paper discusses one aspect – educational aspects – in depth, it still does not mean that other elements are irrelevant. Thus, the chosen approach to tackling gender disparity in STEM is to investigate it through a pedagogical perspective (4).

Moreover, this article tries to uncover ways of developing good pedagogical techniques that can enhance the involvement of females in the field of science. Some of these techniques include gender-based pedagogical methods, designing a curriculum that focuses on the achievements of women, mentoring programs, and early exposure to STEM education. These methods ensure that women feel appreciated and ready to embrace a career in STEM (4). While STEM education remains critical in contributing to the progress of any country and the world at large, this cannot be achieved until the issue of gender equality is dealt with successfully. The gap that exists between males and females in the field of STEM not only denies girls their rights, but it also limits the chances for innovative ideas to arise.

2. Understanding the Gender Gap in STEM

2.1 Conceptualising the Gender Gap

The gender gap in STEM (Science, Technology, Engineering, and Mathematics) involves the systematic inequality in the presence, engagement, and progression of men and women in these areas. The gender gap does not affect any one period of study or work, but is a multi-layered phenomenon that exists throughout the entire educational and occupational journey. Enrolment rates, classroom participation, grades, opportunities, hiring into jobs, and occupying leadership positions are some of the ways through which the gender gap emerges within STEM fields (5).

In terms of enrolment, while the number of female students enrolling in schools around the world is increasing, there is an inverse correlation between their enrolment rates and the advancement of their education. As these students advance in their studies, fewer girls continue to enrol in STEM-related courses. For instance, while women enrol in more STEM subjects in higher education than ever before, their participation is less prominent in specific fields like engineering, physics, and computer science, which are stereotypically male.

The other area where the gender gap can be seen is academic achievement. Studies show that girls score just as high, if not better than their male counterparts in STEM subjects in all levels of learning. But even though they achieve equal, if not better results, girls tend not to pursue further academic study and careers in these fields (5). Therefore, it can be assumed that the basis of this gap is not linked to the actual skills and abilities of the students, but rather to other factors like confidence issues and stereotypical threat, among others.

The "leaky pipeline" theory can be used as a concept to explain the gender gap in STEM areas. It describes how girls start leaving the STEM pipeline along the process of their studies and career paths, from being a teenager, through undergraduate studies, postgraduate education, and into professional employment. Even though the entry-level representation seems relatively stable, when it comes to more advanced educational levels and jobs, there is very little representation among women (6).

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2.2 Global and Indian Scenario

In the international context, gender imbalances in STEM education and careers are still a relevant challenge after many years of policy interventions and campaigning activities by various stakeholders. For example, according to UNESCO, one should admit that the role of women in science and technology has changed insignificantly throughout the decades, and the current situation demonstrates some stagnation in various parts of the world. Such stagnation proves that the underlying factors preventing gender balance cannot be resolved at an individual or personal level (8).

Worldwide, women remain underrepresented in STEM fields like engineering and information technologies. It seems noteworthy that, despite some success in increasing the percentage of women pursuing higher education, little has been achieved in terms of their equal involvement in STEM-related areas of specialisation. Gender stereotypes, discriminatory attitudes, and the absence of supportive environments continue to limit females' access. The case of developing countries is complicated and somewhat paradoxical, especially when it comes to India. In this country, the efforts by the government to make education accessible to women have proven to be quite successful since female enrollment in higher education has increased significantly within the last few decades. However, not all areas of academic disciplines have equal numbers of women; there is a considerable gender imbalance in STEM fields (8).

Women in India are fairly represented in life sciences, medicine, and biology-related fields, but their enrollment rates decrease dramatically when it comes to engineering, technology, and computer science programs. One can assume that there are certain socio-cultural factors that guide women to choose appropriate careers, limiting their opportunities to pursue their interests in other fields. Another important issue in India is connected to the transition from education to professional development, since women are unable to find jobs after completing their degrees. Studies show that even though women comprise 46%-59% of graduates in STEM fields, only 14%-30% of employees work in such industries. These statistics point at significant obstacles women encounter on the job market, such as various forms of discrimination, rigid work conditions, and the inability to fulfil their domestic obligations.

Moreover, there are regional and socio-economic differences that add to the gender disparity in India. Rural women, those from poor economic backgrounds, and women from underprivileged communities experience different kinds of discrimination such as inadequate educational facilities and limited access to the internet and professional success. This adds another dimension to the struggle for attaining gender equality in STEM education and careers.

To conclude, as can be observed in both international and local cases, gender inequality in STEM education remains a complicated problem that is here to stay. Even though some efforts have been made to improve educational accessibility for women, it does not mean that their full participation and success in STEM subjects is not yet an achievable goal (9).

3. Factors Contributing to Gender Disparities in STEM

3.1 Socio-Cultural Norms and Gender Stereotypes

The socio-cultural environment and gender stereotypes have a fundamental importance in determining educational and occupational goals, especially when it comes to STEM disciplines. Since infancy, people are inducted into culturally prescribed gender roles that guide their expectations about acceptable behaviour and interests for both genders, as well as their occupational choices. For instance, in most cultures, including Indian society, girls are expected to become nurturing, sympathetic, and caregiving individuals, while boys are supposed to pursue analytical, technical, and competitive tasks. These socio-culturally prescribed roles have a profound effect on subject choice and career path selection (10).

The portrayal of STEM-related courses as intrinsically masculine subjects, which require analytical skills, aggressiveness, and technological knowledge – traditionally attributed to men – is one of the common gender stereotypes. Such beliefs discourage girls from pursuing careers in STEM-related disciplines because they assume that these fields are not suitable for women. The notion that STEM professions are not compatible with female attributes prevents girls from developing an interest in science and mathematics at a young age (9).

Moreover, educational content frequently lacks equal representation of women in science, hence continuing to stereotype STEM as a field predominantly populated by men. Teachers may be unknowingly reinforcing these stereotypes through their pedagogical practices, like encouraging boys more than girls in science-related activities or making assumptions about how girls perform better outside STEM. All of this gradually contributes to the construction of an educational identity based on gender (10).

3.2 Lack of Confidence and Self-Efficacy

Tightly connected with the problem of socio-cultural factors is that of confidence and self-efficacy of girls studying STEM subjects. The term "self-efficacy" denotes people's conviction in their capacity to carry out particular tasks. In relation to STEM education, this concept is very important because it determines the decision to study and work in the sphere under consideration.

The fact is that girls consistently underestimate their capacities in the area of math and natural sciences while displaying equal academic results compared to boys. There is no doubt that this situation is determined by something else besides real abilities, which are often very close. The reason is that girls who get used to being told that "STEM is not for you" lose confidence in their knowledge and capabilities (11).

The gap widens during the teenage years when they must make decisions that could shape the career paths they will follow later on. The inability to feel confident in their capabilities in the STEM field causes them to shy away from taking up advanced courses and competitions. It also discourages them from following careers that are related to STEM due to the lack of self-belief instilled in them by those around them.

Classroom learning situations that put much focus on competing against each other also work against the benefit of girls, since they like a cooperative environment. Failure to implement interventions that create confidence in themselves serves to maintain self-efficacy as an obstacle to women in STEM (12).

3.3 Absence of Role Models and Mentors

The shortage of female role models and mentors in STEM-related careers is yet another significant aspect that leads to gender discrepancies. Role models play a vital function by serving as a source of inspiration that shows one can be successful in a specific field. Female role models are especially valuable for girls as they can change the stereotype that they may have regarding certain subjects and increase their aspirations. Nevertheless, the fact that women are underrepresented among people working in STEM-related careers makes them less visible as role models and mentors for female students, thus creating a barrier. Without adequate role models, women see STEM careers as those dominated by men, which discourages them from engaging in this area (13).

Finally, a mentor is crucial when maintaining someone's interest in a certain subject. Apart from academic assistance, a mentor can give advice and support throughout a student's academic journey. However, the processes and mechanisms aimed at fostering mentorship may not work properly for female students.

However, in many instances, mentoring programs either lack or are not gender-specific, and therefore fail to cater for the issues that affect girls in their pursuit of STEM fields. This makes it difficult for women to develop strategies that will enable them to deal with any obstacles encountered in their education.

3.4 Institutional and Pedagogical Barriers

Educational institutions and pedagogies can contribute to gender discrimination in STEM education inadvertently. The traditional pedagogy focuses on a lecturing style of education, memorisation, and competitive assessment. The aforementioned educational techniques do not consider the unique preferences and learning styles of all learners. These pedagogies could result in the exclusion of female students from the classroom experience.

The second major factor that influences the creation of stereotypes is curriculum content. The absence of women among the great scientists featured in STEM textbooks contributes to the formation of stereotypical views about STEM. Moreover, gender stereotypes can also be reinforced through case studies and examples provided during the lesson (14).

Finally, the interaction between students and teachers may become discriminatory due to certain behavioural patterns. For example, teachers tend to encourage boys in STEM classes more often than girls. Boys can be called more frequently to give their opinion on some matter and conduct practical experiments. Assessment procedures which emphasize speed and competition over comprehension and cooperation could also marginalise some learners. Without active measures aimed at utilising an inclusive approach in teaching, educational institutions run the risk of perpetuating rather than redressing pre-existing gender inequalities.

3.5 Economic and Regional Factors

Economic and geographic inequalities are some of the key barriers to STEM education for females. Economic inequality impacts the level of resource availability that can facilitate quality education. Poor families tend to favour the education of males over females in situations where there is strict adherence to traditional norms and roles. The education of parents is another barrier to girls engaging in STEM-related activities.

The education of a parent will determine whether they will encourage their daughter to engage in STEM activities. The higher the level of education, the greater the possibility that they will be supportive. Geographical inequality also acts as a barrier because regions that are not urbanized do not have adequate education facilities, instructors, and even technology resources.

Other barriers that girls experience include issues of security and the inability to move around freely, coupled with pressure to marry at an early age. Also, there is another important factor called the digital divide that acts as a major hindrance in the current scenario. The restricted availability of digital equipment and lack of internet connection hampers access to information about STEM among girls from disadvantaged sections of society (15).

On the whole, it can be concluded that several factors, social, cultural, psychological, institutional, and economic, collectively determine the existence of the gender gap in STEM education. Efforts must be made in different directions to tackle these obstacles, including stereotyping, boosting confidence levels, mentoring, improving the pedagogical framework, and providing equal opportunities for all (15).

4. Role of Pedagogy in Addressing Gender Disparities

Pedagogy has a key part to play in moulding how students learn, think about themselves, and what they want to achieve, especially when it comes to STEM subjects. The methods by which the subject is taught, the examples, and the class environment all contribute to how students see themselves and their potential. Pedagogy that is inclusive is critical for overcoming the problem of gender inequalities, as it allows them to be challenged.

Gender-Sensitive Teaching Approaches

Gender-specific pedagogy involves the discovery of bias in the learning process. In most cases, such bias is unconscious and does not even cross teachers' minds, but it greatly influences students' involvement and self-assurance. It becomes important for teachers to actively provide equal chances for boys and girls to participate in classroom activities. It is important to ensure that boys and girls have equal opportunities to take part in classroom discussions and ask questions during lessons, among other actions. The use of gender-free language also assists in preventing the creation of stereotypes.

Inclusive Curriculum Design

The content of the curriculum is instrumental in influencing the views of students concerning gender roles in the domain of STEM. The literature in the field indicates that conventional books tend to downplay the role played by women in advancing science and technology. By contrast, a gender-balanced curriculum takes into account the contribution of women in the field of science and technology and brings about multiple viewpoints. The content of such a curriculum needs to be broad and incorporate various social, cultural, and regional contexts for the purpose of relating to learners (16).

Experiential and Collaborative Learning

Both experiential and collaborative forms of learning have proved themselves to be especially efficient when working with women in STEM classes. These techniques are not limited to mere studying from books and consist of more practical forms of study that include solving problems and teamwork. Working on projects, conducting experiments, and having class discussions provide opportunities for application of theoretical knowledge in practice. Collaboration allows removing competition that usually exists between the learners who are involved in STEM studies.

Early Exposure to STEM

It is important that STEM education is introduced to girls at an early age since it will contribute greatly towards the development of their interest and confidence. Gender roles and stereotypes are developed at a tender age; hence, it is advisable that teachers introduce STEM subjects in ways that can help to dispel stereotypes about gender roles and career choice. Using enjoyable methods such as storytelling, playing games, and engaging in experiments will help girls build both their interests and confidence (17).

Mentorship and Role Model Integration

Mentorship and role modelling are important ways of encouraging women to join STEM courses. Exposure to successful women who have made it in the field encourages and inspires students. Mentors can assist learners in dealing with academic issues, building self-confidence, and making sound career decisions. Universities must set up mentorship systems, conduct workshops and seminars, and emphasise women leaders in their institutions. The success stories of women in STEM fields also contribute to shattering negative perceptions and cultivating a conducive learning environment (8).

To conclude, inclusive pedagogical approaches play a critical role in addressing the gender disparity in STEM education. Through gender-conscious instructional strategies, developing inclusive courses, emphasising hands-on learning, initiating early involvement, and implementing mentorship programs, educational practitioners can create a conducive learning environment for women. These strategies will not only ensure gender equality but will also stimulate creativity and diversity in STEM fields (7).

5. Policy Framework and Institutional Interventions

India's National Education Policy (NEP) 2020 is a milestone move towards inclusive and equitable education, with a focus on addressing gender inequities in STEM areas. Among the major highlights of the policy is the establishment of the Gender Inclusion Fund, which will provide an environment where all girls and other underprivileged segments have equal opportunities in receiving quality education. NEP 2020 encourages interdisciplinary learning, early introduction to science, technology, engineering, and mathematics, and fostering critical thinking and innovation within the curriculum. In addition, NEP 2020 emphasises the significance of ensuring infrastructural parity, safe spaces for learning, and intervention measures to encourage females in science and technology (17).

Teacher training and capacity-building are pivotal for implementing the principle of inclusive education. In this regard, teachers can be viewed as facilitators of change by creating a conducive environment in classrooms and addressing gender stereotypes. Teacher training must emphasise gender sensitivity and empower educators to identify and counteract implicit biases in their pedagogical techniques. Inclusive pedagogy, such as collaborative learning, differentiation, and learner-centered instruction, is also vital for teachers. Besides, dealing with unconscious bias among teachers becomes necessary because classroom conduct may affect a student's confidence and participation in STEM classes (5).

The importance of Digital and Technological Interventions cannot be overstated in enhancing access to STEM education, especially for female students in far-flung and marginalised areas. The use of online learning systems, digital laboratories, and e-learning resources can offer effective ways to make learning more convenient and interesting. Nevertheless, the digital divide, which is caused by disparities in terms of access to technology and digital skills, continues to pose an obstacle. In order to achieve inclusiveness, policy interventions must address issues related to digital infrastructure, affordability, and digital skills among female students (18).

6. Challenges in Implementing Inclusive Pedagogy

- 1 However, there are still many problems with the use of pedagogical strategies:
- 2 Difficulty adapting to new changes in traditional teaching methods

- 3 Insufficient funding and facilities
- 4 Limited knowledge among teachers
- 5 Social and cultural issues
- 6 In order to overcome such obstacles, concerted efforts must be made by various stakeholders.

7. Recommendations

The suggested solutions are designed to eliminate the disparity in terms of gender and education in STEM. To that end, these recommendations focus on both institutional issues and social problems in order to ensure a comprehensive solution.

The first recommendation is connected with gender-sensitive teaching approaches at all educational stages. The point is that such approaches will allow one to avoid stereotypes in the classroom and create conditions when girls are encouraged to discuss STEM-related topics freely and ask their questions (19).

The next step is related to the revision of the current curriculum. It will be possible to achieve this goal by including materials about women who have made significant contributions to science. This factor is important to encourage female students because they can see role models.

Finally, mentoring is an integral part of this process, and meetings with successful professionals who work in STEM may motivate students.

Fourthly, there needs to be improvement in the training of teachers in the area of gender inclusivity. The role of the teachers as key change agents in such instances is very important.

Fifthly, there should be encouragement of early exposure to STEM subjects through interactive and hands-on activities that help girls build confidence early on.

Finally, tackling socioeconomic issues through scholarships and various other means of assistance will ensure that finances do not pose a hindrance to the girls accessing quality STEM education.

All these steps show that the attainment of gender equality in STEM is not only pedagogical but social and political as well.

8. Conclusion

Gender inequality in STEM education is a challenging and complex problem that needs a comprehensive and long-term solution. Though much progress has been made in terms of boosting female enrolment, there are still many differences between women and men concerning the choice of subjects and their career prospects (20). Pedagogy is one of the key tools that may contribute to solving this problem through applying inclusive pedagogical techniques, gender-sensitive curriculum design, and creating positive learning experiences for girls. In the end, equal opportunities for men and women in STEM education are important not just from the perspective of equality but also because they help to promote innovation and progress.

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