IJARASEM

ISSN: 2395-7852

International Journal of Advanced Research in Arts, Science, Engineering & Management

Volume 13, Issue 1, January – February 2026

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.028

International Journal of Advanced Research in Arts, Science, Engineering & Management (IJARASEM)

| ISSN: 2395-7852 | www.ijarasem.com | Impact Factor: 8.028 | Bimonthly, Peer Reviewed & Refereed Journal|

| Volume 13, Issue 1, January – February 2026 |

Women in STEM Education in India: A Path Toward Greater Inclusion and Innovation

Nidhi Saraswat[1], Rishita Agrawal[2], Sanshita Agrawal[2]

PGT, Dept. of Physics, Scindia Kanya Vidyalaya Gwalior, Madhya Pradesh, India[1]

Scholar, Scindia Kanya Vidyalaya Gwalior, Madhya Pradesh, India[2]

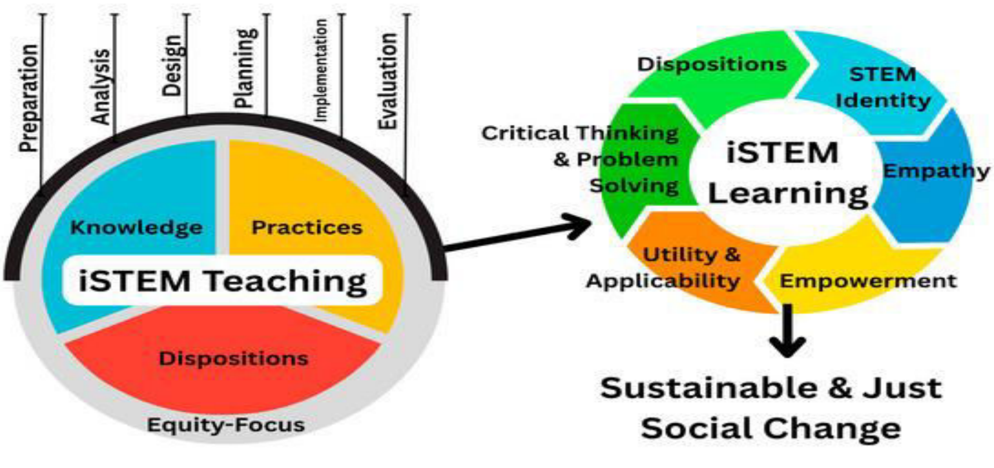
ABSTRACT: STEM-based approaches create dynamic and learner-centered experiences that support long-term academic success and cognitive enrichment, highlighting the need for broader curriculum integration, teacher training, and policy-level support to maximize educational outcomes. Therefore, the present paper examines the representation of women in STEM education in India, drawing on a qualitative analysis of scholarly literature and policy frameworks. It explores the role of policy measures, academic institutions, institutional practices, and prevailing social norms in shaping these outcomes. By identifying key challenges and existing initiatives, the study seeks to enhance understanding of how inclusive educational strategies can promote women's participation in STEM and reinforce India's innovation-driven growth.

KEYWORDS: STEM; academic; women; innovation; challenges.

I. INTRODUCTION

STEM education-encompassing science, technology, engineering, and mathematics, has emerged as a transformative pedagogical approach that emphasizes inquiry-based learning, problem-solving, creativity, and real-world applicability. Science, Technology, Engineering, and Mathematics (STEM) education is widely recognized as a key driver of economic resilience, technological advancement, and innovation in the contemporary world. For an emerging economy such as India, enhancing STEM education is critical to addressing complex challenges including technical transformations, sustainable growth, and global competitiveness. An inclusive STEM ecosystem is thus vital for sustaining long-term national development and innovation. The growing need to develop a population that is proficient in STEM has become increasingly evident, particularly because many of today's most critical global challenges-such as climate change and public health emergencies-can only be effectively addressed through advances in science, technology, engineering, and mathematics. Recognizing this urgency, educators, policymakers, and researchers have shifted their focus toward adopting innovative and forward-looking strategies that move beyond traditional teaching practices and conventional classroom methods (Pinar et al., 2025; Hasim et al., 2022; Hamad et al., 2024; Mahmood et al., 2025). Figure 1 illustrates an integrated STEM (iSTEM) framework that connects equity-focused teaching with transformative learning outcomes.

Fig 1: Conceptualization of iSTEM education



Source: Rimbach-Jones et al. (2025)

On the teaching side, iSTEM is built upon three core components—knowledge, practices, and dispositions—ensuring that students not only acquire conceptual understanding but also develop practical skills and positive attitudes toward STEM. This framework operates through systematic stages, including preparation, analysis, design, planning, implementation, and evaluation, highlighting that inclusive STEM education requires deliberate and continuous effort. Ultimately, the framework suggests that integrated and inclusive STEM education contributes to sustainable and socially just social change by fostering capable, confident, and socially responsible learners.

Over the past few decades, India has made notable progress in broadening access to education across various segments of society. Female enrollment in schools and higher educational institutions has increased, indicating positive trends in educational engagement. However, despite these advancements, women continue to be underrepresented across multiple STEM disciplines, especially at advanced stages of education, research involvement, and leadership positions. This imbalance not only restricts women's individual opportunities but also reduces the diversity of perspectives necessary for innovation. Women's progression in STEM education remains influenced by systemic barriers such as gender-based bias, socio-cultural constraints, and limited institutional support. Traditional gender norms, limited mentorship opportunities, and unequal access to academic and professional networks further constrain women's advancement in STEM fields. These enduring barriers contribute to disparities in academic achievement, career progression, and representation in decision-making roles. In view of this, the present paper aims to examine the role of policy measures, academic institutions, institutional practices, and prevailing social norms in shaping the outcomes of STEM education in special reference to women education.

II. STRUCTURAL DETERMINANTS OF WOMEN'S PARTICIPATION IN STEM EDUCATION IN INDIA

Sustainable development can only be achieved when women actively participate in key decision-making processes across all sectors. Persistent gender bias continues to obstruct inclusive growth, which depends upon equitable representation of women in every domain, including Science, Technology, Engineering, and Mathematics (STEM). Although women today form an important segment of the workforce in STEM-related areas, the field continues to be overwhelmingly male-dominated. Despite global recognition of gender equality as a central development objective—reflected in Sustainable Development Goal (SDG) 5—women still face structural and social barriers that limit their preparedness and access to careers in science and technology. Strengthening women's capacity through targeted training, mentorship, and institutional support has therefore become an urgent priority. Achieving substantive gender equality in STEM will require not only increased representation of women in senior and leadership roles but also equal access to quality education, skill development, and professional advancement opportunities alongside men (Aggarwal et al., 2022).

Historically, STEM disciplines have largely been shaped by male participation, with women encountering institutional obstacles and deeply embedded systemic constraints. However, recent decades have witnessed meaningful progress, as women across the world have begun to challenge entrenched norms, break professional barriers, and contribute significantly to scientific and technological innovation. As more women enter STEM careers, they also serve as mentors and role models for younger generations, thereby strengthening aspirational pathways. Expanding women's representation in STEM is essential not only for fairness but also for building a diverse and inclusive workforce capable of addressing future technological demands. With employment landscapes becoming increasingly technology-driven, STEM competencies are critical for long-term career stability and can contribute to narrowing gender-based wage disparities. Empowering women in STEM also brings diverse perspectives that enhance innovation and problem-solving, which are essential for tackling global challenges such as poverty reduction, skilled labour shortages, and sustainable development. Although many countries have improved gender parity in school enrolment over the past two decades, disparities in performance—particularly in STEM subjects—continue to emerge from an early age and persist throughout educational trajectories.

Chauke (2022) explored the push and pull factors influencing male and female students' decisions to pursue STEM programs at Technical and Vocational Education and Training (TVET) colleges in rural Limpopo, South Africa. Using qualitative methods and focus-group discussions with 20 students, the study applied thematic analysis to interpret participant experiences. Findings indicated that attractive salary prospects, concerns about graduate unemployment, aptitude in mathematics and science, parental educational background, aspirations for independence, and resistance to stereotypical feminine identities influenced students' choices. The study suggested that embedding an Afrocentric perspective within STEM teaching at TVET institutions may strengthen engagement and contextual relevance.

Mqadi (2024) examined school- and parent-related influences on female students' participation in STEM careers in secondary schools within the UGU district municipality of KwaZulu-Natal, South Africa. The study sampled 110 students (45 males and 65 females) across four schools, employing a descriptive research design and questionnaire-based data collection. Statistical tools, including mean and t-test analyses, were used to interpret the data. The findings revealed that socio-cultural expectations, gender-biased curriculum materials, and limited presence of female STEM teachers as role models significantly contributed to low female enrolment in STEM subjects. The study recommended awareness initiatives targeting students, parents, and communities, along with greater recruitment of qualified female STEM teachers to serve as visible role models in secondary schools.

Singh and Singh (2025) investigated gender disparities in STEM education in India, with particular attention to socioeconomic determinants. Using a mixed-methods design, the study combined quantitative data from the All-India Survey on Higher Education (AISHE) 2023 with statistical analysis conducted through SPSS. The results highlighted substantial gender gaps in STEM enrolment, especially among students from lower socioeconomic backgrounds. Variables such as family income, parental education, and regional economic conditions were found to significantly influence female participation and academic outcomes in STEM disciplines. The study emphasized that economic barriers play a central role in sustaining gender disparities and called for targeted policy interventions aimed at expanding access and financial support for women. These findings contribute to broader discussions on educational equity and offer direction for designing initiatives that promote women's sustained engagement in STEM.

Prebreza et al. (2025) investigated barriers to women's entry and continuation in STEM through interviews with high school students. The research identified persistent gender stereotypes, limited availability of female role models, and insufficient encouragement within educational settings as major obstacles. The authors proposed early integration of STEM exposure in schooling, structured mentorship programs, and enhanced institutional backing as strategies to improve women's participation. These measures aim to cultivate interest from a young age and create supportive environments that enable women to thrive in STEM careers.

Rahma et al. (2026) conducted a cross-sectional study in the United Arab Emirates to assess women's retention in STEM careers using a validated questionnaire administered to 165 participants. The study revealed that a larger proportion of women than men perceived gender inequality within STEM fields, and many women reported direct experiences of discrimination. Statistical analysis indicated that men were significantly less likely to report gender-based inequality. Female participants also highlighted insufficient organizational commitment to diversity and inclusion in leadership promotion processes. Thematic analysis of open-ended responses identified recurring challenges, including bias in hiring and promotion, the career impact of motherhood and caregiving responsibilities, and limited institutional flexibility. The study concluded that entrenched stereotypes and structural biases continue to shape women's experiences in STEM, underscoring the need for institutional reforms and proactive governmental measures to foster inclusive environments for women scientists and professionals.

III. BARRIERS AND INSTITUTIONAL RESPONSES TO WOMEN'S INCLUSION IN STEM

Although numerous initiatives have been introduced to promote women's inclusion in STEM, the overall progress has remained limited, and gender disparities continue to persist. One major limitation is that many of these programmes have been implemented on a relatively small scale, restricting their reach across diverse socio-economic groups. As a result, women and girls from marginalized or economically weaker backgrounds often remain excluded. Moreover, the issue is deeply structural and cannot be resolved by focusing solely on individual-level interventions aimed at motivating girls. Broader systemic changes—particularly those addressing public attitudes, institutional cultures, and workplace environments—have received comparatively less attention. Consequently, institutional barriers remain largely intact. Another concern is the limited availability of comprehensive data on women's enrolment, performance, and lived experiences within STEM fields. Quantitative statistics alone are insufficient to capture the complexities of women's professional journeys. There is a pressing need for more detailed tracking systems and richer qualitative insights to better understand the realities women face in STEM careers. Establishing robust and inclusive metrics would enable policymakers to design evidence-based strategies that promote gender equity and create genuinely supportive environments (Tulsyan, 2025).

Zhao et al. (2025) investigated transformative educational approaches through interviews and surveys with 35 women who were currently or previously employed in architecture, construction, and related STEM sectors. The study explored participants' educational trajectories, career pathways, professional growth, workplace relationships, and preferred organizational characteristics. Findings revealed that women continue to encounter persistent challenges, including gender bias, professional isolation, limited opportunities for advancement, inadequate mentorship, and difficulties managing work–life balance. Interestingly, despite improvements in K–12 STEM initiatives, a significant proportion of participants first considered STEM careers only during higher education, often after the age of 19. Many discovered career pathways through digital platforms such as online courses, suggesting that virtual resources play a crucial role in shaping awareness and supporting career development. In contrast, college career services were found to have minimal influence on participants' preparedness. A substantial majority reported either experiencing or observing gender-based discrimination, which affected both their immediate job performance and long-term commitment to STEM careers. Caregiving responsibilities further constrained women's professional choices and growth opportunities. At the same time, participants demonstrated strong engagement with emerging technologies, reflecting adaptability and professional resilience. By combining survey data with in-depth interviews, the study provided a nuanced understanding of systemic barriers and evolving trends. It recommended targeted interventions, including early STEM career exposure, structured mentorship, strengthened career services, harassment awareness mechanisms, inclusive educational practices, and policy reforms to foster gender equity and build a more inclusive STEM pipeline.

Similarly, Nweje et al. (2025) emphasized that the persistent underrepresentation of women in STEM continues to limit innovation and equitable participation in these critical disciplines. Historically rooted social norms, implicit biases, and institutional barriers have contributed to a gender imbalance that restricts diverse perspectives in research and problem-solving. However, increasing global demand for a skilled STEM workforce has intensified efforts to dismantle these barriers. The study examined the multifaceted journey of women in STEM, highlighting cultural, institutional, and personal challenges while acknowledging progress achieved through policy reforms, mentorship networks, and focused inclusion initiatives. Strategies discussed include addressing unconscious bias in educational contexts, strengthening supportive workplace cultures, and ensuring equitable access to leadership opportunities. The paper also underscored the transformative role of digital technologies in expanding educational access, particularly for women in underserved regions. By presenting case studies of successful empowerment initiatives, the authors offered practical models for future interventions and stressed the importance of sustained commitment from governments, academic institutions, and industry stakeholders to create a more inclusive STEM ecosystem.

Cruz (2025) further examined the barriers women encounter in STEM education and professional environments, including gender stereotypes, limited recognition of contributions, work–life balance challenges, and structural inequalities embedded within institutions. Through a comprehensive review and analytical assessment, the study highlighted how systemic biases shape educational pathways and career progression. While policy reforms aimed at promoting equality have been introduced, disparities remain evident in both access and advancement. The study concluded that meaningful progress requires strengthening mentorship programmes, revising curricula to ensure inclusivity, and adopting forward-looking strategies that prioritize representation, empowerment, and long-term structural change.

McCullough (2020) focused specifically on women in academic leadership positions within STEM, conducting a survey to understand the barriers and supports they experienced. The findings revealed that many of the challenges encountered in leadership roles mirrored those faced earlier in STEM careers, including difficulties balancing professional and personal responsibilities, undervaluation of achievements, and experiences of imposter syndrome. Cultural expectations were identified as major obstacles that require sustained societal change. Notably, the most significant forms of support reported by participants were personal in nature—encouragement from spouses, partners, and peers—rather than institutional training or formal organizational mechanisms. This suggests that while individual support networks are crucial, systemic and structural reforms remain essential to create equitable pathways for women in STEM leadership.

Women's participation in STEM is shaped by a complex interplay of structural, social, and institutional factors that operate at multiple stages of their educational and professional journeys. Understanding these interconnected barriers is essential for designing policies and interventions that promote meaningful inclusion and long-term advancement of women in STEM (Oberai et al., 2023):

1. **Factors Affecting Entry into STEM:** Entry into STEM fields is shaped by gendered perceptions, social norms, structural gaps in the education system, and financial limitations. STEM is often perceived as a male-dominated domain, which discourages girls from pursuing science and mathematics from an early stage. School socialisation sometimes reinforces stereotypes, particularly when educators lack gender-sensitive training. Social expectations such as early marriage, mobility restrictions, and prioritisation of domestic roles further limit girls' educational choices. In addition, safety concerns and the distant location of coaching centres and institutions reduce access. Systemic gaps, including weak foundational literacy and limited integration of gender equality in curricula, hinder the development of sustained STEM interest. Financial constraints also play a critical role, as expensive coaching and specialised training are not always prioritised for girls within households.
2. **Factors Affecting Experience in STEM:** Women's experiences within STEM environments are often shaped by isolation, unequal task distribution, biased perceptions of affirmative action, and hiring discrimination. Many

women describe STEM spaces as male-centric, which can create feelings of exclusion and reduce self-confidence. They are frequently assigned administrative or "academic housekeeping" roles that, although necessary, are undervalued and limit research productivity. While affirmative action policies aim to improve representation, inadequate institutional sensitisation may result in stigma if deeper structural inequalities remain unaddressed. Furthermore, assumptions related to marriage and motherhood influence hiring decisions, and age-restricted fellowships disadvantage women balancing caregiving responsibilities during crucial career-building years.

3. **Factors Affecting Retention in STEM Careers:** Retention of women in STEM is significantly influenced by workplace structures, pay disparities, and the dual burden of professional and domestic responsibilities. Rigid working hours, lack of flexibility, insufficient childcare support, and gender-neutral policies that overlook unequal caregiving roles push many women out of the workforce. Bias in performance evaluation and salary negotiation contributes to persistent wage gaps and restricts progression to senior roles. Simultaneously, women often manage both career obligations and primary household responsibilities, creating a double burden that slows career advancement and limits long-term retention.

4. **Factors Affecting Leadership Advancement:** Women's progression into leadership positions in STEM is constrained by limited role models, restricted access to networks and sponsorship, and the persistence of subtle systemic biases. The underrepresentation of women in senior roles reduces mentorship opportunities and weakens aspirational pathways. Exclusion from informal networks and lack of sponsorship further restrict women's ability to navigate institutional hierarchies effectively. Although overt discrimination may be declining, entrenched social norms and invisible barriers—commonly referred to as the glass ceiling—continue to hinder women's advancement to top decision-making positions in STEM fields.

IV. CONCLUSION

STEM education occupies a central position in shaping India's future trajectory of innovation, economic growth, and global competitiveness. As highlighted through the integrated STEM (iSTEM) framework, inclusive and equity-oriented teaching practices are not merely pedagogical enhancements but essential foundations for achieving sustainable and socially just development. While India has made measurable progress in expanding educational access for women, their underrepresentation in STEM—particularly in advanced research, senior academic roles, and leadership positions—remains a pressing concern. This imbalance reflects not individual inadequacy but the cumulative impact of structural barriers, socio-cultural norms, institutional biases, and unequal access to opportunities. The review of literature and empirical evidence discussed in this paper clearly indicate that women's participation in STEM is shaped across multiple stages—entry, experience, retention, and leadership advancement. Gendered perceptions formed during early schooling, financial and socio-economic constraints, limited mentorship, workplace rigidity, and implicit biases collectively restrict women's educational and professional mobility.

Although several policies and initiatives have been introduced, their limited scale and fragmented implementation have reduced their overall effectiveness. Addressing gender disparity in STEM therefore requires systemic transformation rather than isolated interventions. Moving forward, strengthening women's participation in STEM demands a multi-layered approach that integrates policy reform, institutional accountability, inclusive curricula, mentorship networks, flexible workplace practices, and improved data systems for informed decision-making. Early exposure to STEM careers, stronger career guidance mechanisms, visible female role models, and supportive work environments are critical to building sustained engagement. Furthermore, addressing socio-economic inequalities and ensuring equitable access to financial and professional resources must remain central to reform efforts. Ultimately, fostering gender equity in STEM is not solely a matter of representation but of national progress. A diverse STEM ecosystem enhances creativity, broadens problem-solving perspectives, and strengthens innovation capacity. For India to fully realize its developmental aspirations and respond effectively to global challenges, it must create an enabling environment where women can enter, thrive, lead, and shape the future of science and technology on equal footing. True transformation will occur when structural reforms, cultural change, and sustained institutional commitment converge to build a genuinely inclusive STEM landscape.

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INTERNATIONAL STANDARD SERIAL NUMBER INDIA

International Journal of Advanced Research in Arts, Science, Engineering & Management (IJARASEM)