



BRIDGING THE GENDER GAP IN STEM FOR SUSTAINABLE WOMEN EMPOWERMENT: A GLOBAL AND INDIAN PERSPECTIVE

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Abstract

Bridging the gender gap in Science, Technology, Engineering, and Mathematics (STEM) is essential for achieving sustainable women empowerment and inclusive socio-economic development. Despite significant global progress in education and workforce participation, women remain underrepresented in STEM fields due to gender stereotypes, unequal access to educational resources, limited mentorship opportunities, workplace discrimination, and socio-cultural barriers. Globally, women constitute around 35% of STEM graduates and less than 30% of researchers, highlighting the need for targeted interventions and gender-inclusive policies. In India, although women represent a considerable proportion of STEM graduates, their participation in research, industry, and leadership positions remains limited due to structural and institutional challenges.

Women's involvement in STEM contributes significantly to innovation, technological advancement, and sustainable development in sectors such as healthcare, environmental science, biotechnology, engineering, and information technology. STEM education promotes financial independence, professional growth, and leadership opportunities for women, thereby improving their socio-economic status and advancing gender equality. Government initiatives, institutional support, and global policy frameworks play a crucial role in promoting women's participation through scholarships, mentorship programs, and inclusive workplace environments.

This review paper examines the global and Indian perspectives on women in STEM, identifies key challenges and barriers, and highlights strategies and policy interventions needed to bridge the gender gap. The study emphasizes that empowering women in STEM is vital for sustainable development and inclusive national growth.

Keywords: Women in STEM, Gender Gap, Women Empowerment, STEM Education, Gender Equality, Sustainable Development, India, Global Perspective, Innovation, Socio-economic Development

1. Introduction

Science, Technology, Engineering, and Mathematics (STEM) play a fundamental role in shaping modern society by driving innovation, economic growth, and sustainable development. In the 21st century, STEM fields have become essential for addressing global challenges such as climate change, public health crises, food security, environmental sustainability, and technological advancement. However, despite the increasing demand for skilled professionals in STEM sectors, women continue to be underrepresented in these fields across the world. Bridging this gender gap is essential not only for achieving gender equality but also for ensuring inclusive and sustainable development at both national and global levels.

Women's empowerment is widely recognized as a key driver of socio-economic development and social justice. Empowerment involves providing women with equal access to education, employment opportunities, resources, and decision-making power in all sectors of society. STEM education and careers offer significant opportunities for women to achieve financial independence, professional growth, and leadership roles, thereby contributing to their overall empowerment. When women actively participate in scientific and technological fields, they bring diverse perspectives, innovative ideas, and creative problem-solving approaches that enhance the quality of research and development outcomes.

Globally, women represent nearly half of the total population, yet their participation in STEM fields remains disproportionately low. According to UNESCO (2021), women account for only about 35% of STEM graduates and less



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than 30% of researchers worldwide, indicating a persistent gender gap in science and technology. Similarly, reports from the World Economic Forum and UN Women highlight that gender inequality in STEM is influenced by cultural norms, limited access to quality education, lack of role models, and workplace discrimination. These challenges often discourage girls and women from pursuing STEM education and careers, leading to a loss of talent and innovation potential.

In India, the situation presents a mixed picture. While the country has made considerable progress in promoting women's education and increasing female enrollment in STEM courses, their participation in the workforce and research sectors remains limited. According to the All India Survey on Higher Education (AISHE), a significant proportion of women enroll in science and engineering programs; however, many do not continue in STEM careers due to family responsibilities, workplace challenges, and societal expectations. Government initiatives such as **Beti Bachao Beti Padhao**, **Women Scientist Scheme (WOS)**, and **Skill India** aim to encourage women's participation in education and employment, yet gaps remain in implementation and accessibility.

The gender gap in STEM is not only a social issue but also an economic and developmental concern. Studies show that increasing women's participation in STEM can boost national productivity, promote innovation, and enhance economic growth. Diverse scientific communities are more effective in addressing complex global challenges and developing sustainable solutions. Therefore, ensuring equal participation of women in STEM is essential for achieving the Sustainable Development Goals (SDGs), particularly SDG 5 (Gender Equality) and SDG 4 (Quality Education).

This review paper aims to examine the concept of STEM and women empowerment, analyze the global and Indian scenario of women's participation in STEM, identify the key factors affecting their involvement, and explore government initiatives, challenges, and future strategies to bridge the gender gap. By highlighting the importance of inclusive policies and supportive environments, the paper emphasizes the need for collaborative efforts from governments, educational institutions, industries, and society to promote sustainable women empowerment through STEM.

2. Concept of STEM and Women Empowerment

Science, Technology, Engineering, and Mathematics (STEM) represent a group of academic and professional disciplines that are essential for innovation, technological progress, and sustainable development in the modern world. STEM education focuses on developing scientific knowledge, analytical thinking, technical skills, and problem-solving abilities that are required to address complex global challenges such as climate change, healthcare development, food security, environmental protection, and digital transformation. The integration of STEM disciplines has become increasingly important in the 21st century as economies worldwide shift toward knowledge-based and technology-driven growth. In this context, equal participation of both men and women in STEM is crucial for balanced development and inclusive progress.

Women's empowerment refers to the process of providing women with equal rights, opportunities, and access to resources that enable them to participate fully in economic, social, and political life. It involves enhancing women's ability to make decisions, achieve financial independence, and contribute to societal development. Education is widely considered one of the most powerful tools for women's empowerment, and STEM education plays a particularly significant role in this process. By acquiring scientific and technological skills, women can gain access to high-paying jobs, leadership positions, and entrepreneurial opportunities, which contribute to their personal and professional growth. STEM education not only improves women's economic status but also strengthens their confidence, decision-making power, and social recognition.

The concept of women in STEM is closely linked to gender equality and sustainable development. Gender equality in STEM ensures that women and men have equal access to education, training, employment, and leadership opportunities in scientific and technological fields. According to international organizations such as UNESCO and UN Women, promoting gender equality in STEM is essential for achieving sustainable development because diverse and inclusive scientific communities are more innovative and effective in solving global problems. Women bring unique perspectives, creativity, and collaborative approaches to scientific research and technological innovation, which enhance the quality and impact of



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scientific outcomes. Therefore, increasing women's participation in STEM is not only a matter of social justice but also a strategic necessity for economic and technological advancement.

STEM education also plays a critical role in reducing poverty and promoting economic independence among women. In many developing countries, women often face limited employment opportunities and lower wages compared to men. By entering STEM professions such as engineering, information technology, biotechnology, and environmental science, women can access better career opportunities and stable income sources. This financial independence enables them to support their families, invest in education and healthcare, and contribute to community development. As a result, STEM education becomes a powerful tool for improving women's socio-economic status and reducing gender inequality.

Another important aspect of STEM and women empowerment is the development of leadership and innovation skills. Women working in STEM fields often become role models and mentors for younger generations, encouraging girls to pursue careers in science and technology. Their success helps challenge traditional gender stereotypes that associate STEM fields primarily with men. Moreover, women leaders in science and technology contribute to policy-making, research development, and organizational growth, thereby strengthening the overall scientific ecosystem. Encouraging women to take leadership roles in STEM institutions, research organizations, and industries is essential for creating a more inclusive and equitable environment.

The integration of STEM with women empowerment is also closely related to the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 8 (Decent Work and Economic Growth), and SDG 9 (Industry, Innovation, and Infrastructure). Promoting women's participation in STEM helps achieve these goals by ensuring equal access to education, improving employment opportunities, and fostering innovation and technological advancement. Governments, educational institutions, and international organizations are increasingly focusing on gender-inclusive STEM policies, scholarships, and awareness programs to encourage girls and women to pursue scientific careers.

Furthermore, the concept of STEM and women empowerment emphasizes the importance of early education and social support systems. Encouraging girls to develop an interest in science and mathematics from an early age can help reduce gender disparities in higher education and employment. Schools, families, and communities play a vital role in shaping attitudes toward STEM education and promoting gender equality. Providing mentorship programs, career guidance, and supportive learning environments can significantly improve women's participation in STEM fields and help them overcome societal barriers.

In conclusion, the concept of STEM and women empowerment highlights the importance of equal participation in scientific and technological fields for achieving sustainable development and gender equality. STEM education provides women with knowledge, skills, and opportunities that enhance their economic independence, leadership abilities, and social status. Promoting women's involvement in STEM is essential for building an inclusive and innovative society that benefits from the full potential of both men and women. Therefore, strengthening STEM education and ensuring equal opportunities for women should be a priority for policymakers, educators, and society as a whole.

3. Global Scenario of Women in STEM (with Statistics and Reports)

The global scenario of women's participation in Science, Technology, Engineering, and Mathematics (STEM) reveals a mixed picture of progress and persistent gender disparities. Over the past few decades, international organizations, governments, and educational institutions have made significant efforts to promote gender equality in STEM education and employment. Despite these efforts, women continue to be underrepresented in scientific and technological fields worldwide, particularly in engineering, information technology, artificial intelligence, and advanced research sectors. The global gender gap in STEM is widely recognized as a major challenge for sustainable development and innovation.

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), women account for only about 35% of STEM graduates globally, and approximately one in three researchers worldwide is a woman. In some



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countries, the proportion of women researchers is even lower, falling below 10%, which highlights the significant gender imbalance in scientific careers. Furthermore, women hold only around 22% of STEM jobs in G20 countries, which is nearly half their representation in the overall workforce. These statistics indicate that although women are increasingly entering STEM education, their transition into employment and leadership roles remains limited.

The global digital and technological revolution has further exposed gender disparities in STEM fields. Reports from UNESCO and global education monitoring agencies show that women constitute only about 26% of the workforce in data and artificial intelligence, 15% in engineering, and around 12% in cloud computing across major economies. This uneven distribution suggests that women are concentrated in life sciences and healthcare-related fields, while technical and engineering disciplines continue to be dominated by men. Gender stereotypes, lack of confidence in mathematics, and limited access to technical training are identified as key factors contributing to this imbalance.

Regional variations also exist in women's participation in STEM. In developed regions such as Europe and North America, female participation in STEM education has increased significantly, particularly in life sciences, environmental science, and medical research. However, representation remains low in engineering and computer science. In developing regions, including parts of Asia, Africa, and Latin America, efforts are being made to increase women's participation through educational reforms, scholarships, and international collaborations. Some countries in the Arab region have reported higher percentages of female engineering graduates, demonstrating that cultural and policy interventions can positively influence gender balance in STEM fields.

Another important aspect of the global scenario is women's participation in the STEM workforce and leadership roles. Studies indicate that women make up less than 30% of the global STEM workforce and hold a limited number of senior positions in research institutions, universities, and technology companies. Women are also underrepresented in STEM leadership, including professorships, research funding committees, and corporate executive roles. The lack of women in decision-making positions reduces opportunities for gender-inclusive policies and mentorship, further widening the gender gap. In addition, women-led STEM startups often receive less funding and support compared to male-led ventures, which limits their growth and innovation potential.

International organizations have recognized the importance of promoting gender equality in STEM as part of global development strategies. UNESCO, UN Women, the World Economic Forum, and the Organisation for Economic Co-operation and Development (OECD) have launched various initiatives to encourage women's participation in science and technology. These initiatives include global awareness campaigns, scholarships, research grants, mentorship programs, and gender-sensitive policy frameworks. The UNESCO "Call to Action to Close the Gender Gap in Science" emphasizes the need for inclusive education systems, equal career opportunities, and supportive work environments to increase women's participation in STEM fields worldwide.

The global COVID-19 pandemic and rapid digital transformation have also highlighted the importance of women in STEM. Women scientists, healthcare professionals, and researchers played a crucial role in vaccine development, medical research, and public health management during the pandemic. However, reports indicate that women faced increased workload, reduced research productivity, and greater family responsibilities during this period, which affected their career progression. This situation demonstrates the need for flexible work policies and gender-sensitive support systems in scientific and technological sectors.

Furthermore, global research studies show that increasing women's participation in STEM leads to improved innovation, better research outcomes, and stronger economic growth. Diverse scientific teams are more effective in solving complex global challenges and developing sustainable solutions. Gender-balanced research environments promote creativity, collaboration, and knowledge-sharing, which are essential for technological advancement and global competitiveness. Therefore, bridging the gender gap in STEM is not only a matter of equality but also a strategic requirement for sustainable development and economic progress.



In conclusion, the global scenario of women in STEM shows gradual improvement but continued gender disparities in education, employment, and leadership roles. While international organizations and governments are actively promoting gender equality in science and technology, significant challenges remain in ensuring equal participation and opportunities for women worldwide. Strengthening policies, promoting inclusive education, and creating supportive work environments are essential steps toward bridging the global gender gap in STEM and achieving sustainable women empowerment.

4. Women in STEM in India (AISHE, UNESCO, National Policies)

India presents a unique and complex scenario in the global landscape of women's participation in Science, Technology, Engineering, and Mathematics (STEM). While the country has made significant progress in increasing female enrolment in STEM education, challenges remain in translating this educational participation into workforce representation, research leadership, and long-term career sustainability. National surveys such as the All India Survey on Higher Education (AISHE), along with reports from UNESCO and other organizations, highlight both achievements and gaps in India's STEM ecosystem for women.

One of the most notable achievements in India is the high proportion of women enrolled in STEM education compared to the global average. According to AISHE and UNESCO-related assessments, women constitute around **43% of STEM graduates in India**, which is significantly higher than the global average of about 35%. This places India among the leading countries in terms of female participation in STEM education. The AISHE data also show a steady increase in female enrolment in higher education, with women accounting for nearly half of total enrolments and showing substantial growth in postgraduate and doctoral studies over the past decade.

Despite this encouraging trend in education, the transition from academic training to professional careers remains a major challenge. Studies indicate that women represent only around **14% of the research and development (R&D) workforce in India**, highlighting a significant gap between education and employment in STEM fields. This phenomenon is often described as the "leaky pipeline," where women gradually drop out of STEM careers at various stages due to family responsibilities, workplace barriers, and limited opportunities for career advancement. The underrepresentation is particularly visible in engineering, technology, and research leadership roles, where male dominance continues to persist.

The distribution of women across different STEM disciplines in India also shows variation. Women are relatively well represented in life sciences, medicine, and biotechnology, where they often outnumber men in certain courses. However, their participation remains low in engineering, computer science, and advanced technology fields such as artificial intelligence and robotics. Engineering institutions such as the Indian Institutes of Technology (IITs) have historically recorded lower female enrolment, although the introduction of supernumerary seats for women since 2018 has improved gender diversity in these institutions. This initiative reflects the government's commitment to promoting gender equality in technical education and encouraging more girls to pursue engineering and technology careers.

Government policies and national initiatives have played a crucial role in promoting women's participation in STEM in India. Several programs have been launched by the Government of India to support women scientists, researchers, and students. The Department of Science and Technology (DST) introduced the **Women Scientist Scheme (WOS)** to support women who have taken career breaks and wish to return to research. Similarly, the **Knowledge Involvement in Research Advancement through Nurturing (KIRAN)** program aims to provide opportunities for women scientists to contribute to research and innovation. The **Beti Bachao Beti Padhao** campaign promotes girls' education and aims to improve gender equality in all fields, including science and technology. These initiatives focus on providing scholarships, fellowships, mentorship, and research funding to encourage women's active participation in STEM fields.

In addition to government programs, national education policies and institutional reforms have strengthened women's participation in STEM. The **National Education Policy (NEP) 2020** emphasizes gender inclusion, interdisciplinary education, and increased access to science and technology education for girls. It encourages the establishment of gender inclusion funds, flexible learning opportunities, and skill development programs to support women in higher education and



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research. The policy also promotes digital learning and innovation, which can help women access STEM education from remote and rural areas, thereby reducing regional disparities.

Another significant development in India's STEM landscape is the increasing participation of women in research publications and scientific collaborations. Data from academic databases indicate that women contribute to a considerable proportion of research papers in fields such as medicine, biology, and environmental science. However, their representation in senior faculty positions, leadership roles, and decision-making bodies remains limited. The low representation of women in leadership positions reduces opportunities for mentorship and policy influence, which are essential for sustaining gender equality in STEM institutions.

Socio-cultural factors also play a major role in shaping women's participation in STEM in India. Traditional gender roles, family responsibilities, early marriage, and lack of social support often discourage women from pursuing long-term careers in science and technology. Many women face challenges in balancing professional and personal responsibilities, leading to career interruptions and reduced opportunities for advancement. In addition, workplace issues such as gender bias, unequal pay, and limited networking opportunities further contribute to the gender gap in STEM employment.

Despite these challenges, India has shown promising progress in promoting women in STEM through public-private partnerships, industry collaborations, and skill development programs. Technology companies, research institutions, and educational organizations are increasingly focusing on gender diversity and inclusive hiring practices. Initiatives such as mentorship programs, internships, and digital skill training are helping women gain practical experience and improve employability in STEM sectors. This growing support system indicates a positive shift toward gender-inclusive scientific and technological development in India.

In conclusion, the Indian scenario of women in STEM reflects both progress and persistent challenges. While high female enrolment in STEM education demonstrates India's commitment to gender equality, the low representation in workforce and leadership positions highlights the need for stronger policy implementation and institutional support. Government initiatives, educational reforms, and industry participation are essential to bridge the gap between education and employment and to create a sustainable and inclusive STEM ecosystem. Strengthening mentorship, promoting gender-sensitive workplace policies, and addressing socio-cultural barriers will play a crucial role in ensuring long-term women empowerment through STEM in India.

5. Factors Affecting Women Participation in STEM

Women's participation in Science, Technology, Engineering, and Mathematics (STEM) is influenced by a combination of social, cultural, educational, psychological, and institutional factors. Despite global efforts to promote gender equality in STEM, multiple barriers continue to restrict women's entry, retention, and advancement in scientific and technological fields. Research studies and international reports indicate that the gender gap in STEM is not caused by a single issue but by a complex interaction of various structural and socio-cultural factors that operate at different stages of education and career development.

One of the most significant factors affecting women's participation in STEM is **gender stereotypes and social norms**. According to UNESCO, deeply rooted cultural beliefs often portray STEM subjects as masculine domains, leading girls to believe that they are less capable in mathematics, engineering, and technology-related fields. These stereotypes influence career choices from an early age and discourage girls from pursuing STEM education and careers. Socialization processes within families, schools, and communities reinforce traditional gender roles, shaping girls' interests and limiting their confidence in scientific disciplines (UNESCO, 2017; UNESCO, 2023).

Another major factor is **limited access to quality education and learning resources**. In many countries, girls face unequal access to STEM-related educational opportunities, including laboratories, digital tools, and technical training programs. UNESCO reports highlight that gender-responsive teaching materials, trained STEM teachers, and proper infrastructure are



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often lacking, particularly in developing regions. This creates an unequal learning environment where girls have fewer opportunities to develop scientific and technical skills. In addition, the absence of gender-sensitive career counseling and mentorship programs further limits their engagement in STEM subjects (UNESCO, 2023).

Psychological factors, such as low self-confidence, lack of motivation, and fear of failure, also play an important role in shaping women's participation in STEM. Research indicates that girls often underestimate their abilities in mathematics and science, even when their academic performance is equal to or better than that of boys. A systematic review of STEM gender gap studies identified self-efficacy, motivation, expectations, and academic confidence as key determinants of participation in STEM fields. Gender bias and negative stereotypes can reduce girls' confidence and discourage them from choosing STEM careers (Frontiers in Education, 2024).

The **lack of female role models and mentors** is another critical factor contributing to low participation in STEM. When girls do not see successful women in scientific and technological fields, they may find it difficult to imagine themselves in such careers. Studies suggest that the absence of role models creates a cycle where fewer women enter STEM, leading to limited mentorship opportunities for future generations. Role models play a vital role in inspiring young women, providing career guidance, and building confidence in pursuing scientific careers (Hernández-Pérez et al., 2024; UNESCO, 2017).

Workplace environment and institutional barriers also significantly affect women's participation and retention in STEM careers. Women often face gender discrimination, unequal pay, limited promotion opportunities, and lack of supportive work environments in scientific and technological organizations. Research on women's experiences in STEM workplaces shows that gendered organizational cultures, poor work-life balance, and limited career growth opportunities discourage women from continuing in STEM professions. Many women leave STEM careers due to lack of professional support, workplace bias, and challenges in balancing family responsibilities with demanding job requirements (Botella et al., 2019; Nature Humanities and Social Sciences Communications, 2022).

Another important factor is the **burden of unpaid care work and family responsibilities**, which disproportionately affects women. OECD reports indicate that women spend more time on domestic work and childcare than men, which limits their ability to pursue higher education, research, and full-time employment in STEM fields. This unequal distribution of household responsibilities often leads to career interruptions, reduced productivity, and slower career advancement for women. The challenge becomes more significant during critical career stages such as postgraduate education, early research careers, and leadership development (OECD, 2025).

Socio-economic factors and labour market conditions also influence women's participation in STEM. In many countries, STEM careers are perceived as demanding and competitive, which discourages women from entering or continuing in these fields. Wage gaps, job insecurity, and limited career advancement opportunities further reduce motivation among women. Additionally, occupational segregation often leads women to concentrate in life sciences and healthcare, while engineering and technology fields remain male-dominated. This imbalance reduces diversity and limits women's contribution to high-growth technological sectors (OECD, 2019; World Economic Forum, 2020).

Finally, **institutional and policy-related challenges** play a significant role in shaping women's participation in STEM. Although many countries have introduced gender equality policies, their implementation remains inconsistent. Limited funding for women-focused STEM programs, lack of monitoring mechanisms, and insufficient institutional support hinder the effectiveness of these policies. UNESCO emphasizes that addressing gender inequality in STEM requires strong policy frameworks, inclusive education systems, and coordinated efforts from governments, educational institutions, and industries (UNESCO, 2023).

In conclusion, women's participation in STEM is influenced by a complex interplay of socio-cultural, educational, psychological, institutional, and economic factors. Gender stereotypes, limited access to education, lack of mentorship, workplace barriers, family responsibilities, and policy gaps collectively contribute to the persistent gender gap in STEM fields. Addressing these factors requires a comprehensive and multi-dimensional approach that includes gender-sensitive



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education, supportive workplace policies, effective mentorship programs, and strong institutional frameworks. By reducing these barriers, societies can promote equal participation of women in STEM and achieve sustainable women empowerment and inclusive development.

6. Role of STEM in Sustainable Women Empowerment

Science, Technology, Engineering, and Mathematics (STEM) play a crucial role in promoting sustainable women empowerment by providing opportunities for education, employment, innovation, and leadership. STEM education equips women with technical knowledge, analytical skills, and problem-solving abilities that enhance their economic independence and social status. In the context of sustainable development, empowering women through STEM is essential for achieving gender equality, reducing poverty, and promoting inclusive economic growth. International organizations such as UNESCO, the World Bank, and UN Women emphasize that increasing women's participation in STEM contributes significantly to social progress, technological advancement, and sustainable development (UNESCO, 2021; UN Women, 2022).

One of the primary roles of STEM in women empowerment is **economic independence and employment generation**. STEM careers, particularly in engineering, information technology, biotechnology, and environmental science, offer higher-paying and stable job opportunities compared to many traditional professions. According to the World Bank (2022), women working in STEM-related sectors often experience improved income levels and greater financial security, which strengthens their decision-making power within families and communities. Economic empowerment enables women to invest in education, healthcare, and entrepreneurship, thereby contributing to long-term socio-economic development. Moreover, access to STEM careers helps reduce gender wage gaps and promotes equal participation in the labour market (World Bank, 2022).

Another important role of STEM is **enhancing leadership and decision-making capabilities among women**. Women who pursue STEM education and careers often gain opportunities to work in research institutions, technology companies, and policy-making organizations, where they can contribute to innovation and governance. STEM leadership positions allow women to influence scientific research, technological development, and national policies. According to UN Women (2023), increasing women's representation in STEM leadership improves institutional diversity and ensures gender-sensitive decision-making in areas such as healthcare, climate change, and digital transformation. Women leaders in STEM serve as role models for younger generations, encouraging more girls to pursue careers in science and technology and breaking traditional gender stereotypes.

STEM also contributes significantly to **social empowerment and gender equality**. Education in science and technology increases women's awareness of their rights, improves their confidence, and enhances their ability to participate in social and political processes. UNESCO (2021) highlights that STEM education promotes critical thinking, innovation, and problem-solving skills, which empower women to challenge social inequalities and contribute to community development. Women scientists and engineers often work on projects related to public health, environmental protection, and sustainable energy, directly improving the quality of life in their communities. This social contribution strengthens women's position in society and promotes gender equality at multiple levels.

The role of STEM in **sustainable development and environmental protection** is another key aspect of women empowerment. Women scientists and researchers contribute to climate change mitigation, renewable energy development, biodiversity conservation, and sustainable agriculture. Their participation ensures that environmental policies and technological solutions are inclusive and community-oriented. According to the United Nations (2022), women's involvement in environmental and technological innovation is essential for achieving the Sustainable Development Goals (SDGs), particularly SDG 5 (Gender Equality), SDG 7 (Affordable and Clean Energy), and SDG 13 (Climate Action). Women in STEM are actively involved in developing eco-friendly technologies, sustainable agricultural practices, and healthcare innovations that benefit society and protect natural resources.



Digital empowerment and technological inclusion also form an important part of sustainable women empowerment through STEM. The rapid growth of digital technologies, artificial intelligence, and information systems has created new opportunities for women in the global economy. STEM education enables women to develop digital skills, participate in online learning, and access global employment opportunities. The World Economic Forum (2023) reports that increasing women's participation in digital and technological sectors can significantly boost global economic growth and innovation. Digital empowerment also helps women entrepreneurs start technology-based businesses, participate in e-commerce, and access global markets, thereby strengthening their economic independence and social status.

Another important contribution of STEM is **promoting entrepreneurship and innovation among women**. STEM-based entrepreneurship allows women to develop innovative products, start technology companies, and contribute to industrial growth. Women entrepreneurs in biotechnology, information technology, environmental engineering, and healthcare are creating new solutions to global challenges. According to OECD (2022), women-led STEM startups contribute to economic diversification and job creation, although they often face funding and networking challenges. Supporting women entrepreneurs through financial assistance, training programs, and incubation centers can significantly enhance their contribution to sustainable development.

Furthermore, STEM plays a vital role in **improving health and quality of life for women and society**. Women researchers and healthcare professionals have contributed significantly to medical research, vaccine development, and public health innovation. Their work in biotechnology, pharmaceuticals, and environmental health has improved healthcare access and disease prevention. During global health crises such as the COVID-19 pandemic, women scientists and healthcare workers played a critical role in research, treatment, and community health management. This demonstrates the importance of women's participation in STEM for ensuring public health and social well-being (UNESCO, 2021).

In addition, **education and mentorship in STEM create long-term empowerment opportunities**. Mentorship programs, scholarships, and research fellowships help women develop professional skills and build strong academic and career networks. UNESCO and UN Women highlight that mentorship and training programs significantly increase women's retention in STEM careers and improve their leadership potential. Encouraging girls to pursue STEM education from an early age ensures a continuous pipeline of skilled women professionals who can contribute to sustainable development and innovation (UN Women, 2023).

In conclusion, STEM plays a transformative role in sustainable women empowerment by promoting economic independence, leadership, social equality, environmental sustainability, digital inclusion, and innovation. Women's participation in STEM strengthens national development and contributes to global progress by addressing complex challenges through scientific and technological solutions. Therefore, promoting gender equality in STEM is essential for building a sustainable and inclusive society that benefits from the full potential of women's knowledge and skills.

7. Government Policies and Initiatives (Global & India)

Government policies and institutional initiatives play a crucial role in promoting women's participation in Science, Technology, Engineering, and Mathematics (STEM) and reducing gender disparities at both global and national levels. International organizations, national governments, and research institutions have introduced various programs, funding schemes, and policy frameworks to encourage women's involvement in scientific and technological fields. These initiatives aim to provide equal educational opportunities, support career development, and create gender-inclusive environments that promote sustainable women empowerment.

7.1 Global Government and Institutional Initiatives

At the global level, organizations such as UNESCO, UN Women, the United Nations, OECD, and the World Economic Forum have launched several initiatives to address gender inequality in STEM. One of the most significant global efforts is UNESCO's **Call to Action: Closing the Gender Gap in Science**, launched in 2024, which encourages governments,



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institutions, and private organizations to work together to promote gender equality in scientific and technological fields. The initiative focuses on improving STEM education for girls, increasing female leadership in science, and creating inclusive workplaces to ensure equal opportunities for women worldwide. UNESCO emphasizes that women make up only about one-third of researchers globally, highlighting the need for coordinated policy interventions to reduce gender disparities in STEM (UNESCO, 2024).

Another major global initiative is UNESCO's **Gender Equality in Science, Technology and Innovation (STI) program**, which promotes data collection, knowledge sharing, capacity building, and policy development to improve women's participation in STEM. The program includes tools such as the STEM and Gender Advancement (SAGA) toolkit and international research collaborations to support policymakers in designing gender-responsive STEM policies. UNESCO also supports the **L'Oréal–UNESCO For Women in Science Programme**, which has recognized and supported more than 4,000 women scientists from over 110 countries, providing research funding and global recognition to promote female leadership in science (UNESCO, 2025).

The United Nations has also introduced global frameworks to strengthen women's participation in STEM through the **Sustainable Development Goals (SDGs)** and the **UN Inter-Agency Task Team on Science, Technology, and Innovation (IATT)**. This initiative promotes collaboration among UN agencies and member states to ensure gender equality in scientific research and technological development. The **International Day of Women and Girls in Science**, celebrated annually on February 11, aims to raise global awareness about the importance of women's participation in STEM and encourage policy reforms that promote gender equality in science and technology (United Nations, 2020).

In addition, UNESCO launched the **Gender-Inclusive Science Institutions and Systems (GenSIS) Project** in collaboration with international partners to strengthen women's leadership in research and higher education institutions. This initiative focuses on developing inclusive science systems, supporting women researchers, and promoting evidence-based policy solutions to bridge the gender gap in STEM globally. The project is part of the International Decade of Sciences for Sustainable Development (2024–2033), emphasizing the importance of inclusive scientific systems for sustainable global development (UNESCO, 2025).

7.2 Government Policies and Initiatives in India

India has implemented several government policies and programs to promote women's participation in STEM and ensure gender equality in science and technology. The Department of Science and Technology (DST) has introduced the **Women in Science and Engineering–KIRAN (WISE-KIRAN)** program, which is one of the most comprehensive initiatives aimed at supporting women at different stages of their scientific careers. The program includes components such as WISE-PhD, WISE Post-Doctoral Fellowship (WISE-PDF), WIDUSHI, and WISE-SCOPE, which provide research funding, fellowships, and career opportunities for women scientists. The initiative focuses on increasing women's participation in research and addressing challenges such as career breaks and lack of institutional support (DST, 2025).

Another important initiative is **Vigyan Jyoti**, which aims to encourage girls to pursue STEM education, particularly in areas where female participation is low. The program provides career counseling, mentoring, science camps, and academic support to girls from Class IX to XII across multiple districts in India. It aims to create awareness and improve gender balance in scientific and technological fields. In addition, the **Gender Advancement for Transforming Institutions (GATI)** initiative focuses on developing a gender equity framework in STEM institutions by promoting institutional reforms and inclusive policies (DST, 2025).

The Government of India has also launched broader educational and social initiatives that indirectly support women in STEM. The **Beti Bachao Beti Padhao** campaign promotes girls' education and gender equality, while the **National Education Policy (NEP) 2020** emphasizes inclusive education, digital learning, and skill development in science and technology. These policies aim to improve access to STEM education, particularly for girls from rural and economically



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weaker sections. Additionally, programs such as **Skill India**, **Digital India**, and **Startup India** provide training and employment opportunities that support women's participation in technological and entrepreneurial sectors.

Furthermore, the **Women Scientist Scheme (WOS)** introduced by the Department of Science and Technology provides opportunities for women who have taken career breaks to re-enter research and continue their scientific work. This scheme addresses one of the major challenges faced by women in STEM, which is career discontinuity due to family and social responsibilities. Government reports indicate that such programs have helped increase women's participation in research, innovation, and academic leadership in India (Press Information Bureau, 2024).

7.3 Comparative Perspective: Global vs India

A comparative analysis of global and Indian initiatives shows that both levels focus on similar goals, such as improving STEM education for girls, supporting women researchers, and creating inclusive workplaces. However, global initiatives primarily emphasize policy frameworks, international collaboration, and research funding, while Indian initiatives focus more on educational access, career re-entry programs, and institutional reforms. The integration of global best practices with national policies can significantly improve women's participation in STEM and strengthen sustainable women empowerment.

Conclusion of Section

In conclusion, government policies and initiatives at both global and national levels play a vital role in bridging the gender gap in STEM. International organizations such as UNESCO and the United Nations provide policy frameworks and global advocacy, while India has implemented targeted programs like WISE-KIRAN, Vigyan Jyoti, and GATI to support women scientists and students. Strengthening these initiatives through effective implementation, funding, and institutional support is essential to promote gender equality in STEM and achieve sustainable women empowerment.

8. Challenges and Barriers

Despite significant progress in promoting women's participation in Science, Technology, Engineering, and Mathematics (STEM), several challenges and barriers continue to hinder their full and equal involvement in these fields. These barriers exist at multiple levels, including social, educational, institutional, and professional environments, creating a persistent gender gap in STEM education, employment, and leadership. Addressing these challenges is essential for ensuring sustainable women empowerment and achieving inclusive scientific and technological development.

One of the major challenges is **deep-rooted gender stereotypes and societal norms** that discourage women from pursuing STEM careers. In many societies, STEM fields such as engineering, technology, and mathematics are traditionally viewed as male-dominated domains, which creates a psychological and social barrier for women. UNESCO reports indicate that such stereotypes influence girls' subject choices from an early age, leading to lower participation in technical and engineering disciplines. Cultural expectations and traditional gender roles often prioritize family responsibilities over career development for women, limiting their opportunities in STEM fields (UNESCO, 2017; UNESCO, 2023).

Another significant barrier is the **leaky pipeline phenomenon**, which refers to the gradual decline in the number of women at different stages of STEM education and careers. Although many women enroll in STEM programs at the undergraduate level, a large proportion drop out before reaching advanced research positions or leadership roles. This decline is often due to career interruptions, lack of mentorship, workplace discrimination, and limited opportunities for promotion. Studies show that women face greater challenges in transitioning from education to employment and from early-career positions to senior roles, resulting in underrepresentation in leadership and decision-making positions (UN Women, 2022; World Economic Forum, 2023).

Workplace discrimination and gender bias also remain major challenges in STEM sectors. Women often face unequal pay, limited career advancement opportunities, and exclusion from professional networks in scientific and technological



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organizations. Research indicates that male-dominated workplace cultures, lack of gender-sensitive policies, and unconscious bias contribute to the underrepresentation of women in leadership roles. Many women report experiencing discrimination, harassment, and lack of recognition for their contributions, which discourages them from continuing in STEM careers (OECD, 2021; UNESCO, 2021).

The **lack of work-life balance and family responsibilities** is another critical barrier affecting women's participation in STEM. Women are often expected to manage household responsibilities, childcare, and family care, which limits their ability to pursue demanding scientific careers. STEM professions frequently require long working hours, research commitments, and travel, making it difficult for women to balance personal and professional responsibilities. According to OECD and World Bank reports, women spend significantly more time on unpaid domestic work compared to men, which affects their career progression and research productivity (OECD, 2022; World Bank, 2022).

Limited access to funding and research opportunities is also a major challenge for women in STEM. Women researchers often receive fewer research grants and financial support compared to their male counterparts. Studies show that women-led research projects and startups face difficulties in securing funding, which restricts their ability to conduct large-scale research and innovation. This funding gap limits women's contribution to scientific advancement and reduces their visibility in global research communities (UNESCO, 2021; Nature, 2022).

Another important barrier is the **digital divide and technological inequality**, particularly in developing countries. Many women lack access to digital tools, internet connectivity, and technical training, which limits their participation in modern STEM fields such as artificial intelligence, data science, and information technology. The digital divide is more prominent in rural and economically weaker regions, where girls have fewer opportunities to access technology-based education and training programs. Bridging this digital gap is essential for promoting gender equality in STEM and ensuring inclusive development (World Economic Forum, 2023).

Institutional and policy-related challenges also affect women's participation in STEM. Although many governments have introduced gender equality policies, their implementation often remains weak due to lack of monitoring, funding, and institutional support. In many cases, gender policies are not effectively integrated into educational and research institutions, leading to limited impact. Inadequate maternity leave policies, lack of childcare facilities, and insufficient flexible working arrangements further discourage women from continuing in STEM careers (UN Women, 2022; UNESCO, 2023).

The **underrepresentation of women in leadership and decision-making roles** is another significant challenge. Women are often excluded from senior positions in universities, research organizations, and technology companies, which limits their influence on policy and institutional decisions. Leadership gaps reduce opportunities for mentorship and role modeling, making it difficult for younger women to pursue STEM careers. Increasing women's representation in leadership is essential for creating inclusive scientific environments and promoting gender-sensitive policies (World Economic Forum, 2023).

Furthermore, **lack of mentorship and networking opportunities** creates additional barriers for women in STEM. Professional networks and mentorship programs are essential for career development, research collaboration, and skill enhancement. However, women often have limited access to such networks, particularly in male-dominated fields such as engineering and technology. Mentorship programs can help women overcome career challenges, build confidence, and improve professional growth, but their availability remains limited in many regions (UNESCO, 2021).

In conclusion, the challenges and barriers faced by women in STEM are multi-dimensional and deeply rooted in social, institutional, and economic structures. Gender stereotypes, workplace discrimination, funding limitations, digital inequality, and lack of policy implementation continue to hinder women's participation and advancement in STEM fields. Addressing these challenges requires a comprehensive approach that includes gender-sensitive policies, institutional reforms, mentorship programs, and social awareness initiatives. By overcoming these barriers, governments and institutions can create a more inclusive STEM environment that promotes sustainable women empowerment and equal opportunities for all.



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9. Strategies to Bridge the Gender Gap

Bridging the gender gap in Science, Technology, Engineering, and Mathematics (STEM) requires a comprehensive and multi-dimensional approach that addresses educational, social, institutional, and policy-related barriers. Governments, educational institutions, industries, and international organizations must work collaboratively to create an inclusive and supportive environment that encourages women's participation and retention in STEM fields. Effective strategies should focus on improving access to education, strengthening mentorship, promoting gender-sensitive policies, and ensuring equal career opportunities to achieve sustainable women empowerment.

One of the most important strategies is **promoting gender-inclusive STEM education from an early stage**. Encouraging girls to develop an interest in science and mathematics during primary and secondary education can significantly reduce gender disparities in higher education and careers. UNESCO emphasizes the need for gender-responsive curricula, trained teachers, and inclusive classroom environments that eliminate stereotypes and build confidence among girls in STEM subjects (UNESCO, 2017). Schools should integrate practical learning, science laboratories, digital tools, and career guidance programs to make STEM education more accessible and attractive to female students. Awareness campaigns and community engagement programs can further support girls' participation by challenging traditional gender norms and encouraging families to support STEM education for their daughters.

Another key strategy is **strengthening mentorship and role model programs**. The presence of successful women scientists, engineers, and researchers can inspire young girls to pursue STEM careers and overcome self-doubt. Mentorship programs provide guidance, career counseling, and networking opportunities that help women navigate academic and professional challenges. According to UN Women (2022), mentorship and leadership training significantly improve women's retention and advancement in STEM fields. Universities and research institutions should establish mentorship networks, research internships, and peer-support systems to create a supportive academic environment for women.

Providing scholarships, financial support, and research funding is also essential for bridging the gender gap in STEM. Many women face financial constraints that limit their access to higher education and research opportunities. Governments and international organizations should offer scholarships, fellowships, and grants specifically for women in STEM to encourage their participation in advanced education and research. Financial support can help women pursue doctoral studies, attend international conferences, and conduct innovative research projects. The OECD and UNESCO highlight that targeted funding programs for women scientists can significantly increase their participation in research and leadership positions (OECD, 2021; UNESCO, 2021).

Another important strategy is **creating gender-inclusive workplace policies and supportive institutional environments**. STEM organizations should implement equal pay policies, flexible working hours, maternity and childcare support, and anti-discrimination regulations to ensure a safe and inclusive work environment. Gender-sensitive workplace policies help women balance professional and personal responsibilities and reduce career interruptions. The World Economic Forum (2023) emphasizes that inclusive organizational cultures and diversity-focused recruitment practices are essential for increasing women's participation in STEM industries. Companies and research institutions should also promote women's leadership through training programs, leadership development initiatives, and equal promotion opportunities.

Promoting digital inclusion and technological access is another crucial strategy for reducing gender disparities in STEM. The rapid growth of digital technologies and artificial intelligence requires women to develop technical and digital skills to remain competitive in the global workforce. Governments and educational institutions should provide digital training programs, online learning platforms, and technology-based skill development initiatives to ensure equal access to STEM education. Bridging the digital divide, particularly in rural and underdeveloped regions, can significantly improve women's participation in technology-driven fields. The United Nations (2022) highlights that digital empowerment is essential for achieving gender equality and sustainable development in the modern world.



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Encouraging women's entrepreneurship and innovation in STEM is also an effective strategy for bridging the gender gap. Women-led startups and technology-based enterprises contribute to economic growth and job creation. Governments and financial institutions should provide incubation centers, innovation hubs, and startup funding to support women entrepreneurs in STEM sectors. Training programs in business management, research commercialization, and intellectual property rights can help women transform innovative ideas into successful enterprises. According to the World Bank (2022), promoting women's entrepreneurship in STEM can significantly enhance economic empowerment and technological development.

Strengthening policy implementation and monitoring mechanisms is equally important in addressing gender disparities in STEM. Many countries have introduced gender equality policies, but their effectiveness depends on proper implementation and evaluation. Governments should establish monitoring systems to track women's participation in STEM education, employment, and leadership positions. Regular data collection, performance evaluation, and policy reviews can help identify gaps and improve the effectiveness of gender-focused initiatives. UNESCO (2023) recommends evidence-based policymaking and institutional accountability to ensure sustainable progress in gender equality in STEM.

Another important strategy is **increasing international collaboration and knowledge sharing**. Global partnerships among universities, research institutions, and international organizations can help share best practices and promote gender-inclusive STEM policies. Exchange programs, international research collaborations, and global mentorship networks provide women with opportunities to gain international exposure and develop advanced scientific skills. Collaborative initiatives also help developing countries adopt successful strategies from developed nations, thereby improving women's participation in STEM worldwide (UNESCO, 2021).

Furthermore, **community awareness and social support systems** are essential for bridging the gender gap in STEM. Changing societal attitudes toward women's education and careers requires strong community engagement and awareness campaigns. Media, non-governmental organizations, and educational institutions should work together to promote positive images of women scientists and engineers. Public awareness programs can challenge stereotypes and encourage families to support girls' education and career aspirations in STEM fields. Social support systems, including family encouragement and community involvement, play a critical role in ensuring women's long-term participation in science and technology.

In conclusion, bridging the gender gap in STEM requires a combination of educational reforms, mentorship programs, financial support, inclusive workplace policies, digital empowerment, and strong policy implementation. Collaborative efforts from governments, institutions, industries, and communities are essential to create equal opportunities and promote sustainable women empowerment. By implementing these strategies effectively, societies can ensure greater participation of women in STEM, leading to innovation, economic growth, and inclusive development.

10. Future Prospects

The future of women in Science, Technology, Engineering, and Mathematics (STEM) appears promising as global awareness about gender equality and sustainable development continues to grow. Governments, international organizations, educational institutions, and industries are increasingly recognizing the importance of women's participation in STEM for innovation, economic growth, and social progress. With the rapid advancement of digital technologies, artificial intelligence, biotechnology, environmental science, and data-driven research, the demand for skilled professionals in STEM fields is expected to rise significantly. This growing demand creates new opportunities for women to actively participate in scientific and technological development and contribute to sustainable global progress.

One of the key future prospects is the **expansion of digital and technology-based education**, which can help increase women's participation in STEM. Online learning platforms, virtual laboratories, and digital skill development programs are making STEM education more accessible to women, especially in rural and underdeveloped regions. The integration of artificial intelligence, robotics, and data science into educational curricula will provide women with advanced technical skills and improve their employability in the global job market. UNESCO and the World Economic Forum highlight that



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digital transformation can play a crucial role in reducing gender disparities and creating equal opportunities for women in emerging STEM sectors (UNESCO, 2023; World Economic Forum, 2023).

Another important future prospect is the **increasing focus on gender-inclusive policies and institutional reforms**. Many countries are adopting gender-sensitive education policies, equal pay regulations, and diversity-focused recruitment strategies to promote women's participation in STEM. In India, initiatives such as STEM scholarships, research fellowships, and innovation programs are expected to strengthen women's representation in scientific research and technological industries. Similarly, global initiatives led by the United Nations and UNESCO aim to improve women's access to education, leadership positions, and research opportunities. These policy reforms will create a more inclusive and supportive environment for women in STEM fields.

The **growth of women leadership and entrepreneurship in STEM** is another promising area for the future. Women scientists, engineers, and innovators are increasingly taking leadership roles in research institutions, universities, and technology companies. Women-led startups and innovation hubs are contributing to economic development and technological advancement in sectors such as healthcare, environmental sustainability, and digital technology. Encouraging women's entrepreneurship through funding support, incubation centers, and skill development programs will further enhance their participation in STEM and promote economic empowerment. According to the World Bank (2022), supporting women entrepreneurs in technology and innovation sectors can significantly improve national productivity and global competitiveness.

The future also holds significant potential in **strengthening global collaboration and knowledge-sharing networks**. International partnerships among universities, research institutions, and industries can provide women with access to advanced research facilities, training programs, and global career opportunities. Exchange programs, international conferences, and collaborative research projects can enhance women's scientific skills and increase their visibility in the global research community. Such collaborations will help developing countries adopt best practices and improve gender equality in STEM education and employment.

Another emerging prospect is the **integration of STEM with sustainable development and environmental protection**. Women in STEM are expected to play a crucial role in addressing global challenges such as climate change, biodiversity conservation, renewable energy development, and sustainable agriculture. Their participation in environmental science, biotechnology, and engineering can contribute to innovative and sustainable solutions that benefit society. Promoting women's involvement in green technologies and environmental research will support the achievement of Sustainable Development Goals (SDGs), particularly SDG 5 (Gender Equality) and SDG 9 (Industry, Innovation, and Infrastructure).

Furthermore, **social awareness and cultural transformation** will play a key role in shaping the future of women in STEM. Changing societal attitudes toward women's education and careers is essential for reducing gender stereotypes and encouraging equal participation. Media representation, awareness campaigns, and community engagement programs can promote positive images of women scientists and engineers, inspiring young girls to pursue STEM careers. As societies become more inclusive and supportive, women will have greater opportunities to contribute to scientific and technological progress.

In conclusion, the future prospects of women in STEM are closely linked to digital transformation, policy reforms, leadership development, global collaboration, and sustainable development initiatives. With continuous efforts from governments, institutions, and society, women's participation in STEM is expected to increase significantly in the coming years. Strengthening STEM education, promoting gender-inclusive policies, and encouraging innovation will ensure sustainable women empowerment and contribute to a more equitable and knowledge-based global society.



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11. Conclusion

Bridging the gender gap in Science, Technology, Engineering, and Mathematics (STEM) is essential for achieving sustainable women empowerment, inclusive socio-economic development, and global innovation. Women's participation in STEM not only promotes gender equality but also enhances scientific research, technological advancement, and economic growth. Despite significant progress in education and employment, women continue to face multiple challenges, including gender stereotypes, limited access to resources, workplace discrimination, and socio-cultural barriers that restrict their participation in STEM fields.

This review highlights that STEM education plays a vital role in empowering women by providing financial independence, leadership opportunities, and professional growth. Women's involvement in science and technology contributes to innovation, problem-solving, and sustainable development across sectors such as healthcare, environmental science, biotechnology, information technology, and engineering. Global and Indian initiatives, including educational reforms, scholarships, mentorship programs, and gender-inclusive policies, have shown positive impacts in promoting women's participation in STEM. However, challenges such as the leaky pipeline, digital divide, and lack of institutional support still need to be addressed.

To ensure sustainable women empowerment, governments, educational institutions, industries, and communities must work collaboratively to create equal opportunities and supportive environments for women in STEM. Strengthening policy implementation, promoting digital inclusion, encouraging leadership, and increasing awareness can help reduce gender disparities and improve women's participation in scientific and technological fields. Bridging the gender gap in STEM will not only empower women but also contribute to national development, global competitiveness, and a more equitable and sustainable future for society.

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