



## WOMEN IN STEM: AN OVERVIEW PROTOCOL FOR UNDERSTANDING GENDER DISPARITIES ACROSS STEM FIELDS

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### ABSTRACT

Gender disparities in Science, Technology, Engineering, and Mathematics (STEM) remain a persistent global challenge that affects educational equity, talent development, and innovation capacity. This systematic literature review synthesizes evidence from 31 Scopus-indexed empirical and conceptual studies published between 2020 and 2025 to examine the multidimensional factors that contribute to gender inequalities across the STEM pipeline. Using PRISMA guidelines and inductive thematic analysis, the review identifies four major themes: multidimensional barriers shaped by historical, socio-cultural, institutional, and psychosocial dynamics; the interaction between educational systems, institutional environments, and self-related beliefs; strategies and interventions implemented across various contexts to reduce gender gaps; and conceptual or policy contributions that propose structural reforms toward equity. The findings reveal that gender disparities are deeply rooted in cultural norms, biased educational practices, institutional constraints, and internalized psychosocial factors such as self-efficacy and identity misalignment. These interconnected barriers produce a cumulative disadvantage that restricts women's participation, persistence, and advancement in STEM. Effective interventions require multi-level, ecosystem-based approaches that integrate early educational reform, role-model visibility, inclusive pedagogy, institutional transformation, and gender-responsive policy frameworks. This study highlights critical gaps in the literature and provides implications for designing more equitable and sustainable STEM environments. Recommendations for future research include cross-country comparative analyses, intersectional studies, and evaluations of long-term policy impacts.

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### ARTICLE INFO

#### **Keywords:**

*gender disparity; STEM education; women in STEM; gender roles; educational inequality*

#### **Article History:**

Submitted: December 3, 2025

Revised: December 5, 2025

Accepted: January 27, 2026

 <https://doi.org/10.15642/IJGCS>

**HOW TO CITE** Septiyanto, A., et.al (2026). Generation Z's Resilience Amidst The Pressures Of The Gig Economy And The Phenomenon Of "Just Run Away" (Analysis Of Law, Power Relationships, And Gender Responsiveness). *Journal of Indonesian Islam Studies*, Volume 1 (1), 52-70

## Introduction

STEM (Science, Technology, Engineering, and Mathematics) It plays an increasingly essential role in advancing the progress of modern society, particularly through innovation-driven economic growth and the provision of solutions to a wide range of global challenges that are becoming increasingly complex. Digital transformation (Yin, 2024), the demand for sustainable energy (Muneer et al., 2025), and advances in health technologies (Soygüder & Uçkun, 2026) position these fields as strategic sectors that determine the direction of global development. It is within this context that the involvement of women in the STEM ecosystem become increasingly crucial, not only in relation to equitable access and opportunities, but also in its direct connection to our collective capacity to generate creative, inclusive, and relevant ideas (Ambrose, 2024; Camila Francisco de Castro et al., 2025; Meadows, 2016). Broader participation of women enables the emergence of diverse perspectives in problem-solving processes and innovation development (Kurmankulov et al., 2023), thereby strengthening the ability of STEM to respond to the needs of the global society (Mac-lean et al., 2025). Therefore, fostering a more balanced representation of women across STEM disciplines constitutes an essential prerequisite for ensuring that scientific and technological advancements reflect the diversity of the populations that they serve.

Globally, gender inequality in STEM is evident across all stages of the education pipeline, the workforce, and scientific leadership. The UNESCO Global Education Monitoring Report 2023 shows that women represent only about 28% of STEM program applicants, 35% of graduates, and less than 30% of active researchers. This disparity is even more pronounced in certain fields, such as engineering, which graduates only 22% women, computing 20%, and physics less than 25% (UNESCO, 2023). The World Economic Forum Global Gender Gap Report 2024 also notes that women occupy only 28.2% of global STEM jobs, particularly low in advanced technology professions such as AI specialists (22%), cloud computing (14%), and data science (26%) (WEF, 2024). Inequality also persists into leadership and innovation spheres, as evidenced by the UNESCO Science Report 2021, which indicates women hold only 14% of research leadership positions, while the WIPO World Intellectual Property Indicators 2023 shows women account for just 11% of international patent owners (UNESCO, 2021). These findings affirm that barriers for women not only occur at the initial access to education but also limit career mobility, scientific productivity, and their contributions to technological innovation.

In the Asia-Pacific region, gender disparities in STEM manifest in complex and multilayered forms, shaped by heterogeneous social, economic, cultural, and educational conditions. The UNDP Women in STEM in Asia-Pacific Study 2024 indicates that women constitute only 23.9% of STEM researchers, a proportion below the global average. Considerable cross-national variation is evident: Japan reports only 16% female researchers, South Korea 20%, and India 14%, whereas Malaysia and the Philippines demonstrate higher representation at 35–38%. Nevertheless, women's participation in engineering and computing remains below 25% in most countries (UNDP, 2024). In higher education, data from the UNESCO Institute for Statistics reveal that women's enrolment in engineering programs ranges from 18–28%, in computing from 12–22%, and in physics from 10–20% (UNESCO, 2023). Indonesia reflects these regional trends. BPS Thematic Gender Statistics: Women and Science 2023 shows that women represent only 22–30% of the national STEM workforce (BPS, 2023), while the BRIN Indonesian Research Statistics 2023 reports that women account for merely 19% of active researchers. In higher education (BRIN, 2023), PDDikti, (2023) shows that women's participation in engineering programs is 21%, in computing/IT 18–22%, and in physics/mathematics 24–27%. These patterns reaffirm that structural barriers across the Asia-Pacific region and Indonesia emerge not only during formal education but also extend into career transitions, research productivity, and innovative capacity.

Persistent gender inequality in STEM carries significant implications for both women and society at large. At the individual level, low levels of women's representation restrict access to high-quality education, high-income career pathways, and opportunities to attain leadership positions in strategic sectors (McCullough, 2020; Ortiz-Martínez et al., 2023). Psychologically, this condition generates challenges such as lower self-efficacy (Noviyanti et al., 2026), stereotype threat (Koch et al., 2023), and a weakened sense of belonging in STEM environments that continue to be male-dominated (Aelenei et al., 2020). At the societal level, the limited participation of women reduces diversity in innovation processes, which affects the quality of technologies produced and risks perpetuating bias in products, services, and policy making (Bear & Woolley, 2011). Such imbalances

diminish the competitiveness of technology-driven industries, widen socio-economic inequalities, and constrain national capacity to respond to global challenges in an inclusive and sustainable manner (Kovaleva et al., 2021).

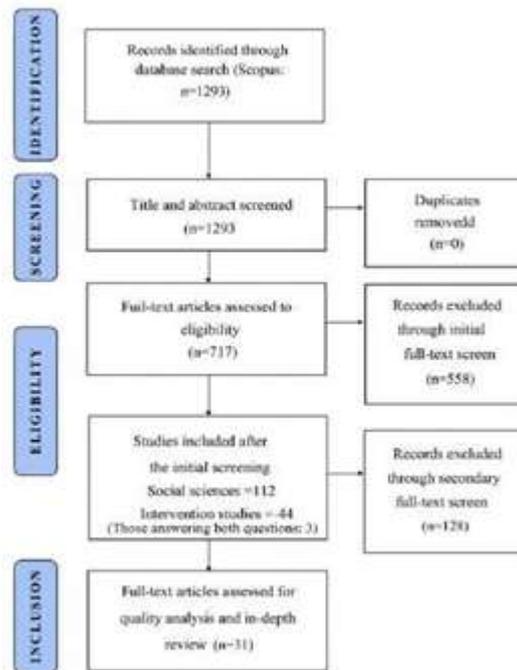
Given the complexity of these issues, a literature review is required to comprehensively examine the factors that perpetuate gender inequality in STEM and to identify the most effective approaches for addressing them. Although the existing literature has extensively explored this topic, most studies remain focused on only one dimension—such as education, institutional factors, or psychology—thereby failing to provide a holistic understanding of how these barriers interact across women's academic and professional trajectories (Wu & Zhang, 2025). This review seeks to address that gap by integrating findings across disciplines, broadening the scope of analysis, and giving a more comprehensive mapping of the characteristics of the barriers faced by women in STEM.

This literature review provides a comprehensive analysis of the multidimensional domains that dictate the dynamics of gender inequality within STEM, delineating how socio-cultural legacies intersect with contemporary institutional structures. The investigation begins by examining the enduring influence of social norms that historically restrict female participation, alongside educational disparities such as unequal access and the scarcity of visible role models. These external barriers are further compounded by systemic institutional biases embedded within recruitment, promotion, and career development trajectories. To provide a holistic perspective, the review incorporates a nuanced examination of psychosocial factors—including stereotype threat, self-perceived competence, and the availability of environmental support—which collectively function to either reinforce or dismantle the obstacles women encounter. By synthesizing these diverse elements, the analysis seeks to elucidate how historical, educational, institutional, and psychosocial barriers interact to sustain persistent gendered patterns across scientific disciplines.

Beyond diagnosing systemic barriers, this study evaluates the efficacy of evidence-based intervention strategies, ranging from macro-level reforms in education and employment policy to micro-level initiatives such as mentoring, leadership training, and the cultivation of inclusive workplace cultures. The implications of fostering an inclusive STEM ecosystem are profound; achieving gender parity is not merely a matter of social equity but a strategic imperative for enhancing the quality of innovation, expanding the national talent base, and bolstering a country's competitiveness in an increasingly knowledge-based economy. Ultimately, a more diverse STEM landscape produces technologies that are more responsive to societal diversity and global challenges. Consequently, this review is structured to address critical inquiries regarding the specific factors contributing to STEM inequality, the interaction of multifaceted barriers, and the identification of the most effective strategies for closing the gender gap.

## Method

This literature review is structured following the systematic review guidelines proposed by Tricco et al. (2015) and the evidence-informed review approach outlined by Tranfield et al. (2003), in order to ensure that the review process is transparent, structured, and replicable. This approach was selected because the literature on gender inequality in STEM remains fragmented, necessitating a review that can synthesize cross-disciplinary findings and organize them into a comprehensive conceptual synthesis. The PRISMA method used for article selection is presented in Figure 1.



Picture 1. PRISMA criterion process

The literature search was conducted using Scopus as the sole database, given its reputation as a comprehensive international journal index relevant to research in STEM, education, and the social sciences. The search was carried out from January to March 2025 and restricted to publications from 2020–2025 to ensure that this review includes only recent studies that reflect contemporary developments related to gender issues in STEM. The search strategy was developed using a combination of keywords such as “gender disparity in STEM,” “women in STEM fields,” “gender gap in science and engineering,” “female participation STEM,” “STEM gender inequality,” and “institutional bias STEM,” combined with Boolean operators to maximize the retrieval of relevant articles. The initial search yielded 1,293 articles. These articles were then screened based on the following inclusion criteria: (1) peer-reviewed journals,

(2) written in English, (3) explicitly address gender issues in one or more STEM disciplines, and (4) provide relevant empirical or conceptual contributions. After applying exclusion criteria (duplicate articles, proceedings, editorials, or narrowly scoped reviews), the number of articles was reduced to 159, and after removing technical duplicates, 31 articles remained for further screening.

### ***Selection of Relevant Articles***

The article selection process was conducted in three stages to ensure accuracy and consistency in the inclusion of studies. In the first stage, two researchers independently reviewed the titles, abstracts, and keywords of the 1,293 articles to evaluate their alignment with the focus of this literature review. Any discrepancies in evaluation were discussed until consensus was reached. In the second stage, the list of eliminated articles was re-examined by a third researcher to ensure that no significant studies were overlooked, following the layered selection approach recommended by Brereton et al. (2007) dan Gupta et al. (2020). In the third stage, all remaining articles were read in full to assess the coherence of content, thematic relevance, and methodological quality. To ensure academic rigor, only articles published in Q1–Q3 journals or those with an impact factor  $\geq 1$  were included. Through this comprehensive

screening process, the number of articles that fully met the criteria and were deemed suitable for final analysis was 31. These articles are subsequently mapped in the PRISMA flow diagram in the results section.

### ***Coding and Analysis Process***

The coding and analysis were conducted using an inductive thematic analysis approach to identify the knowledge structure, thematic patterns, and conceptual relationships within the literature on gender inequality in STEM. Following the analytical framework proposed Jones et al. (2011; 2019), each article in the initial sample was thoroughly reviewed and summarized into descriptive statements that reflected the core phenomena under investigation, such as access to education, gendered perceptions of STEM disciplines, career dynamics, institutional bias, women's representation in research, or psychological factors such as self-efficacy and stereotype threat. This stage was carried out to identify the substantive focus of each study without eliminating methodological nuances and contextual details.

Furthermore, the coding process advanced to the second level by grouping those descriptive statements into initial categories that revealed emerging thematic patterns across studies. At this stage, preliminary categories began to take shape, such as historical and normative barriers that influence public perceptions of women's abilities in STEM; educational challenges such as curriculum bias or unequal access to learning resources; structural biases within academic or industrial institutions; unfair selection and promotion mechanisms; and psychosocial factors that shape women's aspirations and retention. In line with the inductive approach introduced Jones et al. (2011), these categories were not predetermined but emerged from an iterative process of reading, comparing, and mapping patterns of similarity across the articles.

At the third stage, the initial categories were refined into higher-level conceptual themes through a process of consolidation and cross-comparison across studies. This stage involved examining the internal coherence of each theme, the consistency across studies, and contextual variations that could provide additional insights into the complexity of gender issues in STEM. Several key themes emerged, including: (1) historical-cultural barriers that reinforce gender stereotypes in STEM; (2) educational inequalities within the STEM pipeline, including pedagogical biases, a lack of female role models, and implicit exclusion in learning environments; (3) institutional and structural constraints such as recruitment bias, unequal promotion opportunities, and limited representation of women in leadership positions; (4) psychosocial factors influencing motivation, academic identity, and persistence in STEM fields; and intervention and policy strategies recommended in the literature to address gender disparities. The refinement of these themes followed the logic of second-level coding as described by Jones et al. (2019), in which descriptive statements are transformed into thematic categories that explain the phenomenon at a more abstract level.

The final stage of the analysis involved constructing a thematic matrix that mapped the interrelationships among themes and the distribution of thematic frequency across the 31 selected articles. This approach was used to identify the most prominent areas addressed in the literature, fragmented or underdeveloped lines of inquiry, and remaining research gaps. Articles that did not meet methodological standards—such as those with insufficient data description or inadequate conceptual analysis—were removed at this stage, as recommended in high-quality SLRs (Jones et al., 2019). The final coding and analytical outcomes provide the foundation for the thematic synthesis presented in the results and discussion sections.

## **Results**

### ***Description of Literature***

The reviewed studies encompass a diverse range of methodological approaches, educational levels, and sociocultural contexts that collectively illuminate the complexity of gender disparities within STEM education. This section provides a structured overview of the empirical and conceptual works included in the review, highlighting the characteristics of each study in terms of authorship, geographical setting, research focus, participant demographics, study design, and data collection methods. Such a systematic mapping serves as the foundation for understanding how gender-related patterns emerge across different educational environments and STEM domains. By presenting these details in a comparative tabular format, the review allows for clearer identification of convergences and divergences among studies, for instance, differences in participant age groups, national contexts, and methodological rigor, which, in turn, inform the thematic synthesis that

follows. The description also offers insights into how various researchers operationalized constructs such as gender attitudes, STEM motivation, participation patterns, and institutional barriers. This ensures transparency in the selection of evidence and strengthens the validity of the subsequent analysis.

The Table 1 below summarizes the key attributes of the initial set of studies, beginning with those conducted in Rwanda and the Netherlands. These studies represent early indicators of how gender disparities manifest both in technical vocational education and in robotics- integrated STEM classrooms, offering a useful starting point for understanding broader trends across the STEM pipeline.

### **Thematic Analysis**

The thematic analysis synthesizes evidence from thirty-seven empirical and conceptual studies to identify dominant patterns that shape gender disparities across STEM education and career pathways. Drawing upon diverse methodological designs, contexts, and participant groups, the analysis organizes the literature into four overarching themes that collectively reflect the multidimensional and intersecting nature of gender inequities in STEM.

*Table 1. Thematic analysis based on Literature*

No	Tema Literatur	Citation
1.	<b>Multidimensional Barriers in STEM</b>	(Balta et al., 2023; Carla-Cristina L'opez-Canchola & Purata-Sifuentes, 2025; Cuevas & García-arenas, 2022; Gatera et al., 2025; Gero et al., 2022; Hanson et al., 2020; Islam & Jirattikorn, 2024; Jang & Yang, 2025; Kataeva, 2024; Kombe et al., 2025; Ladachart & Ladachart, 2025; Li et al., 2015; Okeke et al., 2025; Permana et al., 2024; Quintana et al., 2025; Wassenauer et al., 2023)
2.	<b>Interactions Across Educational, Institutional, and Psychosocial Systems</b>	(Beroiza-valenzuela et al., 2025; Cernadas et al., 2025; Cuevas & García-arenas, 2022; Diniz et al., 2025; Gatera et al., 2025; Gero et al., 2022; Jang & Yang, 2025; Kataeva, 2024; Kombe et al., 2025; Li et al., 2015; Permana et al., 2024; Piva & Rovelli, 2022; Wassenauer et al., 2023)
3.	<b>Strategies Interventions to Reduce Gender Gaps</b>	(Bermu & Sa, 2025; Bustamante-Mora et al., 2025; Fletcher et al., 2024; Rapoport et al., 2026; Sánchez-Roldán et al., 2022; Vásquez-chaux et al., 2025; Wassenauer et al., 2023)
4.	<b>Conceptual, Policy, and Framework Contributions</b>	2024; Rapoport et al., 2026; Sánchez-Roldán et al., 2022; Vásquez-chaux et al., 2025; Wassenauer et al., 2023) (Bustamante-Mora et al., 2025; Cernadas et al., 2025; Cuevas & García-arenas, 2022; Hyrynsalmi, 2020; Islam & Jirattikorn, 2024; National Center for Science and Engineering Statistics, 2023; Pineda et al., 2025) McLean et al. (2024); Prina & Antilla (2024); Islam & Jirattikorn (2023); STEM Non-Place Authors (2024); Women in Engineering & Gender Studies Authors (2024/25); China STEM Disparity Authors (2025).

Based on Table 2 these themes include: (1) multidimensional barriers rooted in historical, socio-cultural, institutional, and psychosocial factors; (2) the interaction of educational, institutional, and socio-psychological systems that shape academic trajectories and career outcomes; (3) strategies and interventions implemented across various settings to mitigate gender gaps; and (4) conceptual and policy-oriented contributions that provide theoretical, structural, and systemic insights for advancing equity in STEM.

This categorization enables a coherent interpretation of recurring patterns across studies while acknowledging the complexity of gendered experiences within STEM ecosystems. The themes also illuminate how gender inequities are produced, maintained, and occasionally disrupted across different phases of the STEM pipeline—from early schooling to advanced professional roles. The thematic synthesis further highlights consistencies across international contexts and reveals gaps that require continued empirical attention. The following section elaborates the

findings according to the four major them.

Table 2.section elaborates the findings according to the four major them.

No	Authors (Year)	Country	Subject	Sample	Age range	Study design	Data collection tool
1	Gatera et al. (2025)	Rwanda	STEM fields in TVET (IPRC Tumba)	300 students	Mainly 15–19 yrs	Longitudinal descriptive (trend)	Institutional enrolment data; basic stats
2	van Wassenae r et al. (2023)	Netherla nds	Robotics education & STEM attitudes (Grade 7–8)	241 students	±12–15 yrs	Quasi-experimental pre–post	S-STEM survey, robotics course tasks
3	Lopez-Canchola et al. (2025)	Latin America & Caribbea n	Women in metrology (industry & academia)	±150–200 female professionals	Adults	Cross-sectional exploratory	Online structured questionnaire (Likert + open-ended)
4	Okeke et al. (2025)	Nigeria	Women in architecture as STEM career	±130–150 female students	Mostly 18–25 yrs	Cross-sectional exploratory	Closed-ended questionnaire
5	Islam & Jirattikorn (2024)	Banglad esh	Gender barriers in STEM education & SDG 4	– (policy/seco ndary data)	–	policy/docume nt review	National reports, UNESCO, World Bank, prior studies
6	Beroíza-Valenzuela et al. (2025)	Chile	Gender, team composition & collective intelligence in STEM	±20–40 undergraduat es	18–25 yrs	Experimental /quasi-experimental	performance measures, questionnaires
7	Kombe & Matete (2025)	Tanzania	Gender parity trends in STEM HEIs	≈1,500 students	Mainly 18–24 yrs	Longitudinal descriptive (2018–2024)	Institutional statistics, student surveys
8	Malone et al. (2023)	USA	Black girls in Summer Engineering Program (SEEK)	±80–90 participants	±8–13 yrs	comparative	scales, reflections
9	Sefora et al. (2024)	South Africa	Factors motivating Black female learners in STEM streams	±20–40 learners (lihat artikel)	±15–18 yrs	Qualitative exploratory	Semi-structured interviews; thematic analysis
10	Kataeva (2024)	Tajikistan	Female faculty navigating STEM careers	±15–25 female academics	Adults	Qualitative, narrative inquiry	In-depth interviews; narrative analysis
11	Ladachart (2025)	Thailand	Design-based STEM discourse Grade 9	±30–40 students	14–15 yrs	Sociocultural discourse analysis	Video-recorded lessons; transcripts;

12	Jang (2025)	South Korea	South Korean women in STEM careers	±20–30 women	Adults	Qualitative phenomenological	observation Semi-structured interviews; thematic coding
13	de las Cuevas, et al. (2022)	Spain (case study)	Gender factors & higher education choice	200	Late teens	Explanatory case / mixed-method	Surveys, perceived/forecasted fit scales
14	Cyr, et al. (2025)	USA	Girls' forecasted fit in STEM & career interest	(±200+ girls)	Early teens	Experimental vignette study	Surveys, perceived/forecasted fit scales
15	Gutfleisch & Nennstiel (2025)	Likely European context	STEM occupations in vocational education	More than 10 female students	VET students	Quantitative survey / comparative	Questionnaires on occupation preferences
16	Vásquez-Chaux, et al. (2025)	Colombia	Gender barriers in STEM-related green TVET	Stakeholder experts	Adults	MICMAC structural analysis	Expert questionnaires; MICMAC software
17	Diez, et al. (2023)	Probably European	STEM gender stereotypes, self-concept & value	Secondary students	Teens	Quantitative cross-sectional	Stereotype scales; self-concept & value questionnaires
18	Merayo & Ayuso (2024)	Spain	Barriers & supports for STEM choice	Secondary students	Teens	Mixed-method / survey + qual	Questionnaires; open-ended items / interviews
19	Chiang, et al. (2024)	Probably multi-country	Girls in World Robot Olympiad	Girl participants in WRO	Mostly 10–18 yrs	Survey-based descriptive	Online questionnaires; event records
20	Quintana, et al. (2025)	Probably USA/Europe	Self-efficacy & gender gaps in STEM domains	Large student sample	-	Quantitative causal decomposition	Standardized scales; advanced statistical modelling
21	Piva & Rovelli (2022)	European country	STEM graduates & entrepreneurship	Graduate cohorts	Young adults	Longitudinal / econometric	Administrative data; labour market records
22	Abu-Asaad, et al. (2023/2024)	Israel	Gender gap in STEM education	National datasets; plus sample of students	-	Mixed-method within-country	Surveys; interviews; secondary data
23	Cernadas, et al. (2025)	European	Culture & initiatives in	-	-	Mixed (conceptual)	Document analysis;

24	Gottlieb et al. (2025)	Possibly Sweden/ Europe	“Cloak of equality” in STEM expectations & task values	Secondary /undergraduate student	-	Quantitative survey	Questionnaires on expectations, task values, participation Career choice scales; academic variable surveys
25	Diniz, et al.(2025)	Likely Portugal/ Spain	Gender comparisons in STEM vs social sciences	University students	adults	Quantitative correlational	Administrative stats; publication & grant data Literature review; case examples
26	Li, et al. (2025)	China	Women’s participation in STEM research	National-level & institutional data	-	Descriptive statistical / policy analysis	Administrative stats; publication & grant data Literature review; case examples
27	Ewim & Dosunmu (2025)	Likely Europe	Women in engineering & gender studies	(essay-type / review)	-	Narrative / integrative review	Literature review; case examples
28	Jang & Yang (2025)	South Korea	STEM Environmental & cognitive	20 South Korean Women in STEAM	33–49 yrs	Qualitative CQR	Semi-structured interviews Standardized entrepreneurship intention scales
29	Sánchez-Teba et al. (2025)	Spain	Environmental & cognitive factors in entrepreneurial intentions of female STEM students	Female STEM students	18–25 yrs	Cross-sectional survey	Interviews/focus groups; thematic analysis
30	Sánchez-Teba, et al. (2025)	Likely USA/UK	Low-SES students’ motivations to study biology (gendered)	Subsample of LSES students	Late teens	Qualitative case study	Interviews/focus groups; thematic analysis
31	El-Hamamsy, et al. (2023)	Country of original study (likely Spain or other European)	Equity and gender gaps in primary Computer Science	Primary pupils	9–12 yrs	experimental / curriculum reform evaluation	Learning tests; perception surveys

## Discussion

### *Multidimensional Barriers Shaping Gender Inequality in STEM*

#### *Structural and Cultural Forms of Gender Barriers*

Gender disparities in STEM are deeply rooted in social structures and cultural constructions of masculinity and femininity. Studies conducted in Bangladesh, Rwanda, Tanzania, and Colombia (Kataeva, 2024; Kombe et al., 2025; Merayo & Ayuso, 2023) show that societies consistently associate technical ability, logic, and high-risk occupations with men, thereby positioning STEM as a masculine domain. In Eastern European countries such as Poland (Ladachart & Ladachart, 2025), the stereotype that engineering is “too difficult for women” persists despite evidence that female students achieve equal or even higher performance in mathematics and science. Research in Israel (Gottlieb et al., 2025), a country with a relatively high gender equality index, also reveals that gender gaps continue to appear in hard STEM pathways. These patterns are aligned with Gender Role Theory, which explains that social expectations attached to femininity, such as being nurturing, caring, and relational, are often perceived as incompatible with characteristics associated with STEM, which are socially constructed as agentic, competitive, and independent.

Institutional structures further reinforce these cultural barriers. In the Chinese academic context, (Fletcher et al., 2024) report that women remain significantly underrepresented in key positions such as principal investigators, major grant holders, and full professorships. Similarly, female faculty members in Tajikistan describe institutional environments that are male-dominated and exclusive, with informal networks controlling access to resources and career opportunities (Jang & Yang, 2025). The article on the “cloak of equality” (Li et al., 2015) also reveals that ostensibly gender-neutral policies often obscure organizational norms built around the masculine ideal worker model, which makes it more difficult for women to navigate dual roles as STEM professionals and domestic caregivers. Taken together, these structural-cultural constraints form the foundation of gender inequalities that are subsequently reproduced across educational systems and the workforce.

#### *Educational and Psychosocial Barriers Along the STEM Pipeline*

Barriers within the education system emerge from early childhood, continue to develop throughout secondary schooling, and culminate at the transition to higher education or entry into the labor market. Research on early years STEM education (Arnaboldi et al., 2025) demonstrates that stereotypes such as “boys are more suited for technology” and “girls are more inclined toward language-based fields” are already observable before the age of seven. At the secondary level, project-based learning practices in Thailand (Cuevas & García-arenas, 2022) reveal a highly gendered division of labor: boys predominantly occupy technical roles (e.g., measurement, design, fabrication), while girls are directed toward documentation or aesthetic-oriented tasks. In robotics competitions such as the WRO, even girls with strong STEM interest continue to experience marginalization through dismissive attitudes and exclusion from programming roles (Piva & Rovelli, 2022). These patterns illustrate how educational systems reproduce sociocultural biases through seemingly minor micro-divisions of labor that ultimately shape long-term academic identity formation.

Psychosocial factors further exacerbate these barriers. A range of studies report that women tend to exhibit lower STEM self-efficacy than men, despite achieving equivalent academic outcomes (Carla-Cristina L’opez-Canchola & Purata-Sifuentes, 2025; Kuang et al., 2024; Quintana et al., 2025). Women are also more likely to internalize the stereotype that STEM requires an inherently “masculine intelligence,” which leads to a perceived misfit with the field. Moreover, female students place greater value on communal goals—such as contributing to society or helping others—values that are seldom emphasized within traditional STEM education (Hamamsy et al., 2023; Raphael et al., 2025). This pattern aligns with Gender Role Theory: when STEM continues to be framed as an agentic domain that lacks space for communal orientations, women may perceive themselves as “incompatible” with the field, even when their academic ability is entirely sufficient.

### ***Interplay of Historical, Educational, Institutional, and Psychosocial Barriers***

#### *Interactions Between Cultural Norms and Educational Practices*

Cultural norms surrounding the masculinity of STEM do not remain as abstract ideas; instead, they materialize in everyday school practices. Teacher expectations play a critical role: studies (Gottlieb et al., 2025; Wassenaer et al., 2023) show that teachers tend to encourage male students to pursue physics and engineering, while female students are directed toward “safer” fields such as health or social sciences. Peer dynamics further reinforce these norms through comments and task allocation processes that limit girls’ access to technical participation (Kataeva, 2024; Piva & Rovelli, 2022). Even within highly competitive programs such as robotics, female students are subjected to subtle exclusion from advanced technical roles (Piva & Rovelli, 2022).

All of these patterns illustrate the mechanism of social reinforcement as articulated by Gender Role Theory: gender-conforming behaviors are rewarded by the social environment, whereas deviations from established gender norms are subtly discouraged. Female students who are repeatedly assigned to non-technical roles implicitly conclude that they are not “fit” for or not needed within STEM, which subsequently shapes and constrains their academic self-concept.

### ***Psychological Internalization and Institutional Reproduction of Inequalities***

The interaction between learning experiences and institutional structures generates significant long-term effects. Low self-concept and a perceived misalignment between personal identity and STEM (Carla-Cristina Lopez-Canchola & Purata-Sifuentes, 2025; Kuang et al., 2024) lead many girls to opt out of physics or engineering pathways despite strong academic performance (Merayo & Ayuso, 2023; Quintana et al., 2025). For those who persist into higher education and research environments, they encounter organizational cultures that are highly competitive, individualistic, and insufficiently accommodating of domestic responsibilities (Fletcher et al., 2024; Jang & Yang, 2025; Li et al., 2015). The lack of senior female role models (Bermu & Sa, 2025; Islam & Jirattikorn, 2024; Sikhosana et al., 2025) further exacerbates these barriers, as there are few visible figures who can affirm that women can achieve success in STEM without compromising their gender identity.

The cumulative effect of these processes results in the well-known leaky pipeline phenomenon: although women are fairly well represented at the undergraduate level, their numbers decline sharply at later career stages, particularly among senior researchers and leadership positions. Within the framework of Gender Role Theory, this pattern reflects an ongoing conflict between women’s internalized gender roles and the institutionally structured professional roles in STEM that are masculinized. This role conflict becomes a systemic mechanism explaining why women are more likely to exit STEM at key career transition points.

### ***Effective Strategies for Reducing Gender Disparities in STEM***

#### *Strategies Targeting Education, Identity, and Early Formation*

A range of educational interventions has been shown to be effective in addressing gender disparities. Early-years STEM approaches (Arnaboldi et al., 2025) emphasize the importance of representing women scientists in instructional materials, employing gender-neutral language, and designing STEM activities that are embedded in children’s everyday experiences. Similarly, curricular reforms in primary-level computer science that systematically monitor gender-related data have also demonstrated improvements in disciplinary perceptions and female participation (Hamamsy et al., 2023).

Programs targeting vulnerable and underrepresented groups have also demonstrated substantial impact. Engineering camps for Black girls (Masjutina & Stearns, 2025; Sikhosana et al., 2025) and STEM programs for female students in South Africa (Kataeva, 2024) have been shown to strengthen self-efficacy, STEM identity, and career aspirations. These initiatives are effective because they combine safe spaces free from stereotyping, culturally relevant female role models, and STEM projects connected to social issues. Such programs directly disrupt

traditional gender scripts and expand the range of possible feminine identities in STEM.

### ***Structural Strategies for Institutional and Organizational Transformation***

Structural-level interventions are essential for sustaining long-term impact. Studies (Bermu & Sa, 2025; Diniz et al., 2025; Fletcher et al., 2024; Li et al., 2015) consistently emphasize that individual-level change is insufficient if institutions continue to maintain the norms of the masculine “ideal worker.” Consequently, recommended strategies include gender audits, transparency in promotion data, revisions to performance evaluation criteria that account for maternity leave and invisible labor, as well as flexible working hours and childcare support policies.

In addition, mentoring and communities of practice (Bermu & Sa, 2025; Beroízavalenzuela et al., 2025; Cyr et al., 2025; Islam & Jirattikorn, 2024; Jang & Yang, 2025) play a crucial role in enabling women to navigate biased organizational structures. The presence of female role models provides alternative gendered representations and widens the scope of professional imaginaries. Career guidance that reframes STEM as socially meaningful—such as through green jobs, health technologies, or science education—has also been shown to enhance interest and persistence among female students (Hamamsy et al., 2023; Quintana et al., 2025; Raphael et al., 2025).

### ***Theoretical Synthesis: Gender Role Theory as an Integrative Lens***

#### *Gender Roles as the Foundation of STEM Inequalities*

Overall, the findings of this SLR indicate that gender is not merely a background variable, but a structural foundation that shapes women’s entire experience in STEM. Gender Role Theory explains that girls are socialized into communal values from early childhood, while STEM is constructed as an agentic domain. The misalignment between self-concept and the prevailing image of STEM generates identity tensions that lead to lower self-efficacy, reduced STEM aspirations, and withdrawal from hard-STEM pathways.

This situation is further exacerbated by institutions that adopt masculine work norms, requiring women to navigate two sets of roles that are difficult to reconcile: the competitive technical professional and the gendered expectations of domestic responsibility. These dynamics demonstrate that gender inequality in STEM is not a consequence of deficiencies in women, but a manifestation of the gendered structure of roles itself.

### ***Using Gender Role Theory to Guide Interventions and Policy Reform***

Gender Role Theory not only delineates the mechanisms underlying gendered disparities in STEM, but also offers a conceptual scaffold for designing structural change. Effective interventions are those that move beyond numerical inclusion to fundamentally interrogate and reconfigure the gendered scripts that construct STEM as a male-dominated domain. Early educational initiatives, the presence of culturally relevant female role models, mentoring systems, and gender-responsive curricula function to broaden the symbolic and social boundaries of femininity within STEM. Concurrently, institutional and policy reforms restructure occupational norms so that they no longer presume a masculine “ideal worker.”

A multi-layered approach—encompassing educational, psychosocial, organizational, and policy levels—provides a sustainable trajectory for reducing gender inequity. The evidence underscores that meaningful transformation cannot be achieved by focusing on women’s deficits, but rather by reengineering institutional practices and reshaping dominant socio-cultural constructions of gender within STEM.

## **Conclusion**

This systematic literature review demonstrates that gender inequality in STEM is a complex and layered phenomenon shaped by the interplay of socio-cultural norms, educational practices, institutional structures, and psychosocial processes. Across the examined studies, women

consistently encounter historical stereotypes, unequal access, biased classroom practices, exclusionary institutional cultures, and psychological pressures such as low self-efficacy, stereotype threat, and misalignment between personal identity and the perceived culture of STEM fields. These barriers accumulate across the educational and career pipeline, producing a persistent leaky pipeline effect that limits women's representation in advanced STEM education, professional pathways, leadership roles, and research productivity.

The findings also show that interventions can be effective when they adopt a holistic, multi-level approach. Programs targeting early childhood STEM perceptions, inclusive classroom pedagogies, identity-affirming experiences, mentoring structures, and institutional or policy reforms all demonstrate measurable improvements in participation and persistence. However, isolated interventions are insufficient. Sustainable change requires systemic transformation of the gendered norms embedded in STEM culture, recruitment and promotion practices, and the broader societal expectations that shape gender roles. By integrating Gender Role Theory as an interpretive lens, this study underscores that progress toward equity demands not only supporting women to fit into existing structures, but reshaping the structures themselves to value diversity, communal goals, and inclusive excellence.

This review advances current understanding by offering a consolidated thematic framework that maps how barriers originate, interact, and reproduce across the STEM ecosystem. The synthesis highlights critical opportunities for policy development, institutional redesign, and future research—particularly intersectional studies, longitudinal tracking of intervention outcomes, and comparative analyses across cultural contexts. Collectively, these insights contribute to the broader mission of creating STEM environments that are equitable, sustainable, and capable of harnessing the full potential of diverse talent.

### Acknowledgements

The authors would like to express their sincere appreciation to the Faculty of Tarbiyah and Teacher Training, UIN Sunan Ampel Surabaya, for the continuous academic support and research facilitation that made this study possible. Special thanks are extended to the supervisors and colleagues whose constructive feedback significantly strengthened the depth and clarity of the manuscript. The authors also acknowledge the contribution of various scholars whose works formed the foundation of the systematic review presented in this study. Finally, heartfelt gratitude is conveyed to all individuals and institutions that provided encouragement throughout the research and writing process.

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