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A systematic review of gender disparities in STEM education

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Abstract

This systematic review aims at three goals: (1) to identify gender disparity in the study of science, technology, engineering, and mathematics (STEM), (2) to analyze the effects of interventions aimed at reducing this disparity, and (3) to characterize gaps in the literature that need to be addressed by future research and practice. Based on the preferred reporting items for systematic reviews and meta-analyses framework in the Scopus and Web of Science databases, 19 peer-reviewed studies were systematically identified and analyzed from 2013 to 2023. The evidence suggests that the gender gap in STEM is due to the interplay of a diversity of social, cultural, educational and psychological factors, none of which is single cause. Institutional, community, and societal structures are still very much gendered, and factors that hinder women's entry into STEM include exposure to gender stereotyping at an early age, which becomes more severe with age; lack of self-efficacy in STEM; a lack of representation in influential STEM roles; and an absence of inclusive STEM institutional cultures. Gender-ability stereotypes in STEM are now well-established to become entrenched early in life, prior to high school, and to become more entrenched as students' progress through school. The impact of mentoring programs, early STEM education, exposure to relatable role models, and STEM programming specifically targeting stereotypes is mixed, though there is recent evidence in the form of a meta-analysis that indicates a near-medium overall effects size from these interventions; effectiveness was found to depend on the type of intervention, educational level, and location. Similarly, a growing number of randomized studies of brief role-modelling interventions have established that one-time exposure, even in low-resource settings, can influence adolescents' career aspirations, and especially girls' aspirations to pursue STEM careers. Key recommendations are early intervention, role modelling and mentoring programs, curriculum development and teaching, institutional policy change, and improved engagement of families/communities. The need for continued multi-level strategies to promote gender parity in STEM education and for future research and policy directions is highlighted.

Keywords: gender gap, STEM education, systematic review, gender disparity, gender equity

INTRODUCTION

The gender gap in science, technology, engineering, and mathematics (STEM) fields continues to shape global educational and workforce dynamics, limiting individual opportunities and constraining the diversity of knowledge produced by science and technology. Beyond individual career opportunities, the underrepresentation of women in STEM has systemic implications: it narrows the diversity of perspectives that

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Contribution to the literature

- This study makes connections between disorganized information in an integrated way, indicating that the gender disparity in STEM is a result of multiple factors, none of which are single or dominant.
- It measures the effectiveness of intervention using evidence from meta-analysis, reporting almost a medium overall effect for mentoring, early education and role-model programs and identifies impacts by type of intervention, level of education and location.
- It connects findings to actionable research and policy gaps; develops concrete multi-level recommendations on research and practice.

shape scientific agendas, reduces the pool of STEM talent available to innovation economies, and creates structural inequalities that disadvantage women throughout their lives (Dasgupta & Stout, 2014; Lariba, 2024). The gender gap persists despite decades of awareness campaigns and numerous targeted interventions—a persistence that highlights the need for theoretically grounded, multi-level, and contextually sensitive approaches rather than piecemeal remediation.

This review is motivated by the persistent underrepresentation of women in STEM education globally and the lack of a comprehensive, theoretically grounded synthesis of the literature from 2013 to 2023. The aims of the review and the guiding research questions are set out explicitly in the following section.

Aim of the Review

This systematic review aims to review and analyze studies that occurred between 2013 and 2023 to look at the gender gap in STEM education. Specifically, the review aims to uncover the social, cultural, educational and psychological determinants of women's underrepresentation of women in STEM, assess the effectiveness of interventions to date, and recommend avenues for future research and practice. The review emphasizes the STEM education contexts (e.g., K-12, higher education) and not workplace or industry contexts. The following research questions will guide the review: (RQ1) What are the key features of the studies that examined the gender gap in STEM education that appeared between 2013 and 2023? What reviewed studies cite as factors leading to underrepresentation of women in STEM? (RQ2) What are the social, cultural, educational and psychological barriers found across the studies reviewed? (RQ3) What is the effectiveness of interventions for closing the gender gap and what factors appear to make them effective? (RQ4): What policy, practice and research recommendations emerge from the reviewed studies?

BACKGROUND

STEM subjects play a pivotal role in the knowledge economies of today and have been acknowledged nationally and globally as drivers of innovation, economic and social development. Inclusive STEM education is explicitly defined as a goal in both the European Commission's Horizon Europe program and the United Nations sustainable development goal 4, which sets binding targets for gender-equitable, inclusive education globally. Nevertheless, a significant gender deficit persists in STEM from secondary school course selection through to high-level academic and industry roles. UNESCO figures indicate that only 33% of the world's researchers are women—a proportion that falls further in engineering (15%) and information and communications technology (ICT) (18%). As a result of this structural underrepresentation, individual opportunity is limited and diversity of scientists and their research agenda and questions decreases (Hill et al., 2010; Wang & Degol, 2017). In this review, the gender inequality through the lens of education and policy is put in its broader academic and policy environment, and the following different mechanisms for sustaining this inequality are discussed in STEM education in other cultural contexts (Hill et al., 2010; Wang & Degol, 2017). In this review, the gender inequality through the lens of education and policy is put in its broader academic and policy environment, and the following different mechanisms for sustaining this inequality are discussed in STEM education in other cultural contexts.

Gender difference in STEM education has been a focus of coordinated research and findings across several disciplines. However, the field is still divided with the studies analyzing only isolated variables without any theoretical comparative syntheses. Systematic reviews bring to the fore the complexities of barriers encountered by women in STEM (e.g., Cheryan et al., 2017; Ganley & Lubienski, 2016). This has been a decade in which policy interest has increased and research methodologies have diversified, but which has yet to be synthesized in a single review. This review aims to fill that void by reviewing empirical work from 2013 to 2023, with specific goals being to identify cause(s), compare the effectiveness of interventions, and offer future directions for research and policy. A large preregistered meta-analysis of 98 studies spanning 33 nations confirms that this pattern is not a recent artefact of any single educational system: gender-ability stereotypes favoring male competence in computer science, engineering, and physics emerge by around age six and grow more pronounced as girls progress through school, underscoring why interventions launched before adolescence may carry particular weight (Miller et al., 2024).

Conceptual Definitions

Before getting onto the specifics some words need to be explained as they are often used interchangeably in the derogative literature. Three words are used interchangeably in derogative literature and need to be defined before getting into the specifics. Gender gap is the quantitative disparity in representation, participation and attainment between women and men in STEM studies. Gender disparity is a more complex phenomenon than gender differences in access, treatment and outcomes which include qualitative differences relating to access to jobs, employer treatment of women and men and women and men's aspirations for employment. Gender equity is the ideal of giving all genders (males, females, and transgender people) equal and fair treatment, that may be provided in different ways to address past inequalities. These are not synonymous: a study on enrolment ratios will look into the gender gap; a study on sense of belonging will deal with gender disparity; a program evaluation may be voiced as a contribution to gender equity. The following are used throughout this review, in particular. Further, as is common among scholars (Hyde, 2014), this manuscript separates the concepts of sex, which relates to biologically-determined aspects, from the concept of gender, which points to sociocultural aspects of roles, norms and identities. The gender gap in STEM is seen as socially constructed even if studies quantify the gender gap using a binary notion of sex.

Theoretical Framework

This review is based on an integrated framework based on four complementary theoretical perspectives. These are grouped here as a way of analyzing these various aspects of the gender gap on the individual, interpersonal and structural level and to structure the findings and synopsis in the subsequent part of the document.

Particular to social cognitive career theory (SCCT) (Lent et al., 1994, 2000), social self-efficacy beliefs, outcome expectations, and personal goals influence career interests, goals, and actions, which in turn are influenced by contextual supports and barriers. In this review, SCCT conceptualizes outcomes of STEM self-efficacy, STEM motivation, and career goals for the girls. Within this framework, papers showing the impact of low self-efficacy as a barrier are understood (e.g., Alam et al., 2021; Kinkopf & Dack, 2023) as well as papers focusing on outcome expectations changing based on the use of role models (e.g., Gonzalez-Perez et al., 2020; Guenaga et al., 2022).

The expectancy-value theory (EVT) of achievement (Eccles et al., 1983; Wigfield & Eccles, 2000) suggests that students' expectations of success and subjective task values (intrinsic, attainment, utility, and cost) are the factors that affect choice in achievement. EVT is particularly valuable for understanding gender differences in STEM subject choice and persistence as it is evident that when objective achievement is similar to boys' girls may have lower expectations about their chances of success in the STEM subject and lower value of their skills in that area (Eccles, 2011; Wang & Degol, 2017). Various included studies are related to constructs from the EVT, especially as they refer to task value attributions, which are associated with gender (Merayo & Ayuso, 2023; Sevilla et al., 2023a).

Activated by the knowledge of negative group stereotypes, stereotype threat theory (STT) (Spencer et al., 1999; Steele & Aronson, 1995) identifies a bought-in to the group stereotype that causes anxiety and cognitive load to adversely affect performance and identification with the threatened domain. The stereotype about a lack of ability, belonging, and persistence in STEM can negatively affect women's performance (Casad et al., 2017; Schmader, 2024). The lens is especially important for research results regarding experiences of hostile classroom interactions (Millar et al., 2022), and non-traditional role model interventions (Gonzalez-Perez et al., 2020).

According to Bem's (1981) gender schema theory (GST), people create cognitive frameworks (gender schemas), which helps them structure knowledge and Stiles and Stiles' (1991) role schemas help them organize information about acceptable roles for men and women. GST can also provide explanations for the generally male-dominated perception of STEM as a male-dominated field (Cheryan et al., 2017), the way this perception is reinforced through mission-driven STEM curricula and pedagogical approaches, and how this lack of non-traditional images of women in STEM is cyclical. This lens is used to interpret studies of gendered stigmas on STEM occupations (Martin-Gamez et al., 2022; Verdugo-Castro et al., 2022) and the value offered by diverse role models (Millar et al., 2022).

Bem's (1981) GST proposes that individuals develop cognitive structures (gender schemas) that organize information about appropriate attributes and roles for women and men. In STEM, GST helps explain why STEM fields are widely perceived as masculine domains (Cheryan et al., 2017), how this perception is maintained through curriculum and pedagogy, and why the absence of non-traditional images of women in STEM is self-reinforcing. Studies on gendered imagery of STEM careers (Martin-Gamez et al., 2022; Verdugo-Castro et al., 2022) and the importance of diverse role models (Millar et al., 2022) are interpreted through this lens.

Together, SCCT, EVT, STT, and GST form a complementary multi-level approach spanning individual cognitive processes, interpersonal dynamics, and socio-structural influences. Findings are analyzed with reference to these frameworks throughout the review, enabling theoretically coherent interpretation of diverse empirical evidence. This integrative approach moves beyond descriptive aggregation toward substantive theoretical contribution, as alignments and tensions between theoretical predictions and empirical findings are examined in the discussion.

Promoting an inclusive and fair environment that helps society depends on gender equality in STEM, especially in educational settings. Several important elements arising from the highlighted work environments emphasize the importance of gender equality in STEM education. Gender-responsive teaching in STEM is essential for the development of gender-sensitive attitudes and the reduction of gender inequalities. The research on STEM pre-service teachers in Greece and Spain underlines the lack of confidence among future educators in their ability to teach gender knowledge and convey gender-sensitive values. This disparity implies that gender mainstreaming in STEM education falls short without sufficient training and institutional support, hence maybe sustaining current gender prejudices and disparities in these sectors (Miralles-Cardona et al., 2023). Institutional initiatives that create structured support for women in STEM—including targeted mentoring, equitable evaluation practices, and transparent promotion pathways—have been identified as key mechanisms for improving both the working environment and women's career progression in STEM fields.

Achieving gender equity in STEM is essential to promote a more inclusive environment to tackle systemic barriers that impede women's involvement in STEM ascription (Mehranpour et al., 2024; O'connell & McKinnon, 2021). It has been proposed that the relative scarcity of exceptional mathematical abilities among women could be a cause of career inequalities in STEM, but research suggests the scarcity of exceptional mathematical ability is not the primary cause of these inequalities. Hence it is essential to make systemic change to improve gender parity in STEM (Mann & DiPrete, 2013) Moreover, teachers can be gender-biased with an impact on students' educational trajectory, which in turn can contribute to ongoing gender disparities in LE in STEM fields (Andersen, 2023).

Gender strategies to encourage females to enter the STEM fields should take into consideration the women's perception of belonging and confidence in STEM (Pietri et al., 2018). Promoting inclusion of both males and females in STEM education helps to address gender stereotypes and biases and ensure a competitive workforce (Reinking & Martin, 2018). One way to remove gender stereotypes and create a positive learning climate for everyone is to incorporate the gender perspective into students' study in engineering, or to promote diversity within the fields of STEM (Gonzalez-Gonzalez et al., 2020; Warsito et al., 2023).

To achieve gender equality in STEM (Kong et al., 2020), the study emphasizes the importance of beginning early education programs, enforcing stricter measures against gender discrimination, changing work environment practices to be more inclusive, and creating improved gender discrimination assessment criteria. Furthermore, solving this gender bias in STEM education is key, as it contributes to an explanation for the continued lack of women in STEM jobs and therefore to stereotypes (Hess & Kunz, 2024). Understanding gender variations and including them into the curriculum can help to solve gender inequities and enhance the results of STEM education (Saggi, 2018).

Furthermore, influencing women's motivation and career aspirations in STEM disciplines include the social surroundings, STEM promotion, gender bias, and sexual harassment (Leaper & Starr, 2019). Reducing current gender bias in educational materials and interventions can assist women's positive implicit connection with STEM to be strengthened and obstacles to gender equality to be lowered (Farrell et al., 2020; Parker et al., 2016).

To build a more inclusive and varied STEM workforce, then, encouraging gender parity in STEM education is crucial. By means of educational programs, legislative changes, and interventions addressing gender prejudice, stereotypes, and institutional hurdles, one can contribute to close the gender gap in STEM education and provide equitable opportunity for every person.

Scale and Scope of the Gender Gap

A complementary systematic review of studies indexed in Web of Science (WoS), Scopus, and Education Resources Information Center (ERIC) between 2012 and 2022 corroborates the breadth of this problem, finding that self-efficacy, motivation, expectations, and stereotype-attribution beliefs are the factors most consistently implicated in the gender gap across the literature, with growth-mindset-oriented learning experiences emerging as the most frequently recommended remedy (Beroíza-Valenzuela & Salas-Guzmán, 2024). The gender gap in STEM education is a complex problem, including academic positions, income, and representation. Studies reveal that gender-based pay differences are somewhat widespread in several STEM disciplines. For instance, women in Poland make 20% less than men in their first year following graduation; the difference grows with time. Inequality is most pronounced among mathematics graduates, exceeding 25%, while it is less than 3% among chemistry and earth science graduates (Zając et al., 2024). In the USA, women in computer science earn about 86.6

cents for every dollar earned by men; compositional effects narrow the gap slightly, but women still earn 9.1 cents less per dollar than their male counterparts (Sassler & Meyerhofer, 2023). In secondary education, fewer female students show interest in STEM and generally prefer fields such as health and education (Ito & McPherson, 2018). Boys' motivation comes from financial incentives, whereas girls' motivation comes from social influence. Teachers and families tend to encourage boys to engage more in STEM, highlighting the need for gender-sensitive education and visible female role models (Merayo & Ayuso, 2023). Gender stereotypes and biases from teachers can affect students' educational trajectories, but these biases are not always statistically significant and can vary according to teachers' demographic characteristics and cultural capital (Andersen, 2023). Gender discrimination in the academic world, especially in tenured positions, continues to persist. While nearly half of assistant professors in STEM fields are women, the percentage of women drop to 45.4% of associate professor and 32.8% of full professor/tenured faculty members in STEM (Galvin et al., 2024). Strategies to narrow the gender gap in STEM should be holistic and cover everything from gender sensitivity in STEM education to opportunities, including providing equitable access and opportunities, to creating a supportive environment from STEM schools through to the workplace and beyond. These initiatives should be customized to especially target the particular difficulties and prejudices women encounter at various phases of their STEM careers tenured positions, continues to persist (Andersen, 2023; Merayo & Ayuso, 2023; Sassler & Meyerhofer, 2023; Zając et al., 2024).

Females' underrepresentation in STEM is a complex issue that has multiple contributing factors. While a gender difference in the potential availability of degrees in STEM persists, research shows that at the high school level, a gap may be closing between what men and women are learning and becoming. This means it is an important time of the student's life to understand this difference (Legewie & DiPrete, 2014). Additionally, mentioned as a significant factor behind the gender imbalance in STEM jobs is underrepresentation of women in STEM fields (Warsito et al., 2023).

Research has highlighted the role of gender stereotypes, gender bias in self-evaluations, and the desire gap between women and men in their motivation to participate in STEM programs and fields (Wan, 2023). Important underlying factors that influence gender disparities in STEM roles that have been highlighted include the importance of addressing women's socialization, peer pressure and marginalization in the sector (Reinking & Martin, 2018). While evidence suggests that the role of discrimination is becoming less prominent over time it has been discovered that discrimination contributed to the under-representation of women in some STEM disciplines and pay inequality (Sassler et al., 2017). Specific interventions that suggest gender differentiated instruction with middle school students and resource optimization to address gender gaps in STEM education have been suggested (Gao, 2024; Ibuola, 2024). Riegle-Crumb and King (2010) have concluded that studying gender differences in STEM studies has revealed the interrelatedness of gender and race/ethnicity, which requires further research to adequately understand the complexities in STEM gender variations. Last, but not least, is the imbalance in the STEM domains influenced by factors in social, cultural and educational arenas that are a recurring issue. A multifaceted approach of mentoring, the reduction of stereotypes and inclusion of diversity can help plug these gaps and reveal the nuanced contexts that sustain gender disparities in STEM.

There are several factors that may explain this gender disparity in STEM fields, including educational paths and societal stereotypes and institutional biases. These are some of the main drivers of this enduring inequality identified in research (Wang & Degol, 2017). Learning journeys are significant. For instance, in Chile, the organization of the secondary education program substantially explains differences in STEM participation at higher education levels by gender. There is a positive relationship between enrolments in university STEM programs and the availability of STEM related courses in academic disciplines; however, this does not ensure high retention rates. Additionally, there appears to be a greater benefit to STEM early practical courses for males than females. While some secondary STEM courses might reach a bigger proportion of female students, it would not prevent this gap without providing additional support and motivation for female students in all educational fields (Sevilla et al., 2023a). Research has also examined gender differences in occupational preferences; however, contemporary scholarship emphasizes that such differences are primarily socially constructed and reflect gendered socialization rather than innate dispositions (Jasko et al., 2019; Su et al., 2009).

Women's involvement in STEM is also much influenced by self-perception and social stereotypes. Research shows that during mathematical experiences, girls perceive themselves as less skilled in mathematics than boys and feel more anxious about mathematics than boys do, thus affecting their choices for STEM careers (Ayuso et al., 2021). Gender stereotypes, self-evaluations, and distinct motivations of males and females play a significant role in keeping inequity alive in STEM fields (Wan, 2023). Seasonably, gender socialization is an additional factor to gender bias in STEM careers, with the socialization of women from STEM for domestic skills, and mathematical intelligence for men (Tandrayen-Ragoobur & Gokulsing, 2022).

Gender stereotypes, particularly in STEM subjects that are overwhelmingly male-dominated (e.g., computer science or engineering), negatively impact women's social cohesion and self-concept cohesion to the extent that they hinder women from being drawn to these subjects and finding their place in them (Schmader, 2024). The structural composition of STEM disciplines can cause gender discrimination in particular affecting women, because most course components are male-dominated (Gaulee & Boateng, 2019). To correct inequalities in STEM should be taken into consideration the cultural norms, gender roles and STEM barriers (Lariba, 2024).

Peer perceptions of these gender discrimination and stereotypes also impact women's participation in STEM (Salehi et al., 2019). Leaders of STEM roles, usually boys, tend to be encouraged more than girls in STEM activities, which strengthens preconceived notions and impacts on girls' self-assurance and interest in STEM (Merayo & Ayuso, 2023). The role of gender gaps in STEM performance compounds the lack of women in the highest-level STEM. To achieve more gender-equality in STEM professions, it will be crucial to build a more inclusive culture in STEM work environments that is skeptical of, and actively works against, male-dominated norms (Sassler et al., 2017).

In essence, gender disparity in STEM education is the product of complex, mutually reinforcing interactions among educational structures, sociocultural norms, psychological mechanisms, and economic constraints. Effectively addressing this disparity requires comprehensive, theoretically informed approaches: reforming educational pathways, challenging stereotypic cultural narratives, providing targeted mentoring and role model support, and tackling the structural economic inequalities that render STEM access unequal. Addressing these challenges at multiple levels—individual, institutional, and structural—is essential to building genuinely inclusive and equitable environments for women in STEM.

Socio-Cultural Context

A number of social phenomena have shaped the disparity in gender representation in STEM disciplines. These variables encompass conventional gender conventions, societal prejudices, educational methods, and cultural attitudes, all of which contribute to the lack of female representation in STEM fields. A comprehensive grasp of these factors is essential for formulating tactics to eliminate the gender disparity in STEM. This is due to a combination of factors including traditional gender norms/societal stereotypes and norms, societal bias, teaching practices and cultural attitudes which impact women's involvement in STEM. An overview of all these needs should be broad enough to enable strategies to be developed that will reduce the gap in STEM between men and women. Cultural and traditional values and expectations play an important role in women's participation in STEM. Specific imposed gender roles, such as those China has imposed on girls, are one such factor impacting girls' self-efficacy and interest in STEM work (Chan, 2022). This pattern is not confined to any single country: a recent study of Spanish secondary school students similarly finds that the lack of STEM vocations among girls is bound up with sociocultural expectations and limited exposure to relatable role models, reinforcing the case for context-sensitive sociocultural interventions rather than a one-size-fits-all approach (Hernández-Pérez et al., 2024).

There is also an impact of the attitude of cross-culturality towards the education decision making in relation to education and gender roles. Cultural attitudes in discrimination against girls in education are thus an important factor in the existence of gender wage gaps, but in certain countries, gender specific preferences for STEM education do not necessarily lead to wider gaps (Aldén & Neuman, 2022). There are fewer women working in these STEM occupations and fewer in these occupations who are perceived as 'women's work' as well as women taking STEM courses, which can affect the social visibility of women in these occupational fields, and can diminish women's feeling of belonging and identification with STEM courses. Many times, educational systems reinforce these preconceptions, which could deter girls from studying STEM fields (Martín-Gámez et al., 2022). Verdugo-Castro et al. (2022) explore how prejudices, preconceptions and societal expectations influence women's presence in higher education programs of study that lead to STEM careers. They can affect the decision-making power of women, opportunities and experiences of women in STEM education and STEM careers. This review synthesizes recent research on sociocultural factors that influence the gender gap in STEM education, drawing on studies that examine cultural norms, institutional practices, and socialization processes across diverse national contexts. This gender gap is attributed to gender biases in the instructional strategies/content. For example, low participation of women in STEM has a negative impact on the Pygmalion effect (lack of performance that leads to low expectations) (Martín-Gámez et al., 2022; Wang & Degol, 2017).

Social support of teachers and parents positively and significantly affects students' STEM related career goals. But there are gender differences in the ways that it impacts career future. For example, parents' beliefs in the career interest play larger roles in female students' STEM career goals, whereas self-efficacy plays larger roles in male students' STEM career goals (Lv et al., 2022). Perceptions of STEM are gendered and are rooted in gender stereotyping and/or in social constructions. Outreach intervention(s) are needed to deflect these negative inputs and increase a representation of STEM careers that are more reflective of contemporary society including an educational curriculum that instills a positive perception of STEM careers in the mind of the students and their parents (Verdugo-Castro et al., 2023). However, in a male culture of STEM this male dominance is not an old and outdated thing, it needs to be systematically changed. Importantly these are norms which are also key in the debate on catalyzing the change, in the implementation of policies of diversity, equity and inclusion (DEI) inside professional societies (Leibnitz et al., 2022).

The results also show the detail of the solutions as well as the degree to which the problems may manifest in a context of women not outnumbering men in STEM. Work for change in the academic environment and challenge all those misconceptions with improved space to hold, access and thrive women in STEM is crucial. In addition, teaching gender-inclusive learning and offering longer-term opportunities to be exposed to alternative models of women in STEM would be particularly promising at reducing gender disparities in STEM by first addressing individual girl's beliefs about the value of the task and then at the beliefs about their own self-efficacy in STEM (Eccles et al., 1983) and then by wider cultural signaling decision making in relation to education and gender roles. Cultural attitudes in discrimination against girls in education are thus an important factor in the existence of gender wage gaps, but in certain countries, gender specific preferences for STEM education do not necessarily lead to wider gaps. (Aldén & Neuman, 2022) There are fewer women working in these STEM occupations and fewer in these occupations who are perceived as 'women's work' as well as women taking STEM courses, which can affect the social visibility of women in these occupational fields, and can diminish women's feeling of belonging and identification with STEM courses. Many times, educational systems reinforce these preconceptions, which could deter girls from studying STEM fields (Martín-Gámez et al., 2022). Verdugo-Castro et al. (2022) explore how prejudices, preconceptions and societal expectations influence women's presence in higher education programs of study that lead to STEM careers. They can affect the decision-making power of women, opportunities and experiences of women in STEM education and STEM careers. The review should focus on the most recent research related to the gender gap in STEM (attempting to broaden research, considering the different sociocultural factors that influence the gender gap in STEM education). This gender gap is attributed to gender biases in the instructional strategies/content. For example, low participation of women in STEM has a negative impact on the Pygmalion effect (lack of performance that leads to low expectations) (Martín-Gámez et al., 2022; Wang & Degol, 2017). Social support of teachers and parents positively and significantly affects students' STEM related career goals. But there are gender differences in the ways that it impacts career future. For example, parents' beliefs in the career interest play larger roles in female students' STEM career goals, whereas self-efficacy plays larger roles in male students' STEM career goals (Lv et al., 2022).

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METHODOLOGY

This systematic review examines the gender gap in STEM education, with particular emphasis on the factors contributing to women's underrepresentation. Specifically, it investigates how curricular practices, institutional policies, and targeted interventions have been implemented to address this disparity and assesses the evidence for their effectiveness. The current literature was evaluated using a detailed method which was based on the recommendations of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) (Moher et al., 2009; Rethlefsen et al., 2021).

The methodology part provides a detailed explanation of the methodology used, which was necessary in order to identify several relevant studies, assess and select them. In the first step a proper search strategy was designed and used to search both Scopus and WoS databases for possibly interesting papers. Afterwards, the studies were studied with a set of predetermined criteria of inclusion/exclusion for relevance to the inquiries of the research.

Table 1. Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Publication type	- Peer-reviewed journal articles - Conference proceedings - Book chapters	- Non-peer-reviewed articles - Opinion pieces, editorials, letters to the editor - Theses or dissertations
Time frame	2013-2023	Before 2013 or after 2023
Language	English	Non-English
Study focus	- Gender gaps in STEM education - K-12 or higher education settings - Factors contributing to gender disparities - Interventions addressing gender gap	- Primary focus on workplace/industry settings - Not specifically addressing gender issues in STEM education - General education topics without STEM/gender focus - Single-gender environments without comparison
Geographical scope	Any country or region	N/A
Research methods	- Qualitative, quantitative, mixed-methods - Empirical research (case studies, surveys, experimental designs, longitudinal studies)	- Purely theoretical papers without empirical data - Literature reviews or meta-analyses
Population	K-12 and higher education students	Exclusively pre-K or adult education outside formal higher education
Accessibility	Full text available in English	- Full text not available in English - No accessible full text

Data Collection Process

1. Database selection: Two major academic databases were selected for this systematic review:
   - Scopus
   - WoS
2. Search query: The following search query was used for both Scopus and WoS, adapted to each database's specific syntax:
   - Scopus: TITLE-ABS-KEY ("gender gap" OR "gender disparity" OR "gender inequality") AND TITLE-ABS-KEY (STEM OR "science education" OR "technology education" OR "engineering education" OR "mathematics education") AND TITLE-ABS-KEY (education OR school OR classroom OR curriculum) AND NOT TITLE-ABS-KEY ("workplace" OR "industry" OR "career")
   - WoS: TS = ("gender gap" OR "gender disparity" OR "gender inequality") AND TS= (STEM OR "science education" OR "technology education" OR "engineering education" OR "mathematics education") AND TS= (education OR school OR classroom OR curriculum) NOT TS= ("workplace" OR "industry" OR "career")
3. Time frame: The search was limited to studies published between 2013 and 2023, covering a 10-year span.
4. Initial results:
   - Scopus: 295 records
   - WoS: 183 records
   - Total initial records: 478
5. Duplicate removal: 155 duplicate records were identified and removed. Remaining records after deduplication: 323
6. Screening process: The 323 unique records were screened based on titles and abstracts, applying inclusion and exclusion criteria (**Table 1**). This process focused on studies examining the gender gap within educational settings, excluding those primarily concerned with workplace or industry contexts.
7. Full-text review: 79 articles were selected for full-text review based on the initial screening.
8. Final selection: After thorough full-text analysis, 19 records met all inclusion criteria and were included in the final review (**Figure 1** and **Figure 2**).

The study focuses specifically on the gender gap within educational levels and contexts. Studies primarily addressing gender gaps in work processes or industry settings were excluded from the final analysis.

Data Analysis

A thorough analysis of 19 papers was conducted in this systematic review. The information analysis is designed based on the aim of the study and to give a comprehensive knowledge. The authors, year of publications, title, methodologies, research techniques and country of study for each study were collated first. This information was summarized following the PRISMA criteria of Moher et al. (2009) and Page et al. (2021). This descriptive analysis gave an overview of the studies reviewed and facilitated identification of researchers' trends in the research field.

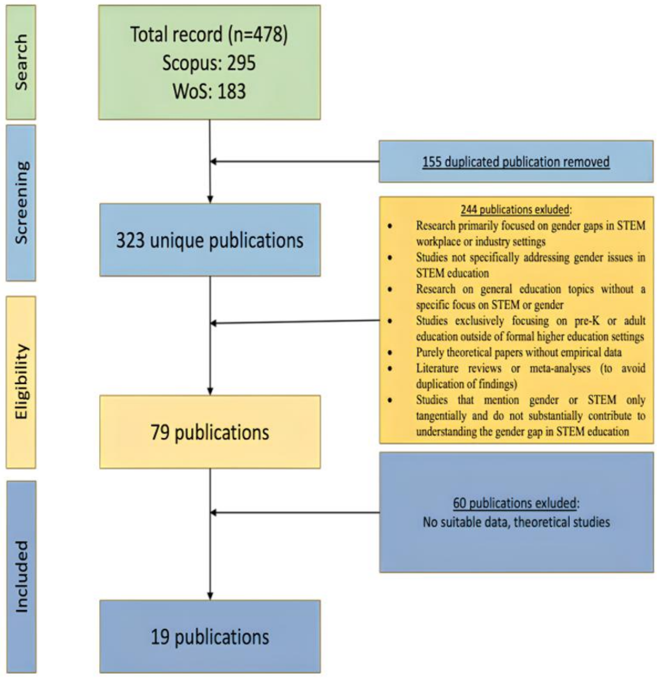

Figure 1. Data collection process for gender gap in STEM (the authors' own elaboration)

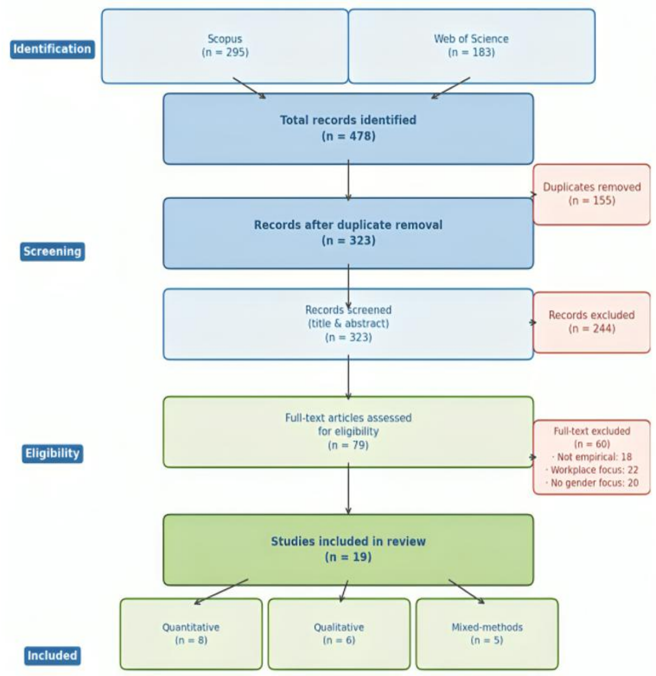

Figure 2. PRISMA flow diagram in data collection process (the authors' own elaboration)

Thematic analysis method has been used as suggested by Braun and Clarke (2006) after descriptive analysis. In this way, the full texts of the selected articles had to be read very carefully, and the relevant information had to be picked out of and summarized within the selected articles, the concepts had to be categorized and interconnected into larger themes. The goal of this process was to discover common themes and patterns in the research. Thematic analysis was crucial to vice understand complex nature of the gender gap in STEM field.

Finally, the themes and categories were defined to come to a synthesis of the research findings, in the next phase of the analysis process. In this stage, the finding motivations of the gender discrepancy expressed in studies were systematized and analyzed. Furthermore, the measures for closing the gender gap taken by the studies that were analyzed were summarized. This synthesis process gave an overarching view of solutions and interventions that can be taken forward to address gender inequalities in STEM.

To ensure reliability and objectivity in the analysis process, all data analysis team members read all of the studies alone. Each study was discussed by the team and coding was done after a common understanding was reached. This helped to standardize and more reliably look at each case yet also allowed for those multiple viewpoints were considered.

The thematic analysis was carried out in the following steps as defined by Braun and Clarke (2006): familiarization with data, initial coding, searching for themes, reviewing themes, defining and naming themes, and writing up. Despite the focus on qualitative research, this approach was adapted and applied in systematic reviews of mixed-methods evidence (Nowell et al., 2017) and was chosen here because of its inductive logic with the primary analytic aim being to establish patterns throughout mixed empirical studies. All 19 studies were read independently and twice, once by two members of the research team who read closely for the purposes of independent coding. Incumbencies in coding were discussed until an agreement was reached between the two different researchers, contributing to increase the coding consistency. Initial codes that can be examples include stereotype internalization, self-efficacy deficit, peer discouragement, and mentorship access. These codes were grouped into four main themes:

(1) social and cultural factors,

(2) educational and psychological factors,

(3) role models and support systems, and

(4) interventions and their effectiveness.

Scopus and WoS were selected because they provide the broadest and most credible coverage of peer-reviewed research in STEM, education, and social science. Although the ERIC database was evaluated during initial planning, a pilot search revealed that fewer than 15 unique records were identified that were not already retrieved from the two primary databases, representing less than 20% novelty. The marginal yield from ERIC did not justify the additional screening burden, and the decision not to include it as a separate database was therefore methodologically defensible. Regarding the final sample of 19 studies: while systematic reviews can encompass varying sample sizes, the decision to retain 19 studies reflects strict adherence to the inclusion and exclusion criteria (**Table 1**), which explicitly excluded purely theoretical papers, meta-analyses, and studies focused on workplace rather than educational contexts. A smaller but methodologically coherent sample allows for deeper thematic synthesis and more rigorous quality appraisal than a larger but heterogeneous corpus would permit (Booth et al., 2016). The one conference proceeding included in the review—Gonzalez-Gonzalez et al. (2020)—was retained because it was published in the peer-reviewed proceedings of the IEEE Global Engineering Education Conference, which applies double-blind review, and its content directly addressed the gender gap in engineering education within the defined scope of the review. In the case of Mozahem et al. (2019): the search term excluded workplace and industry contexts but this paper was considered due to its focus on undergraduate students' learning experiences and career decision making processes within a university engineering program, which is within the scope of the review (K-12 to higher education). The study's career focus was evaluated as being more in regard to the retaining and persistence in STEM as a phenomenon than to a predominant career orientation. In terms of the quality of the included studies, the mixed methods appraisal tool (Hong et al., 2018) was used. This tool also provided the opportunity to conduct a quality assessment on quantitative studies as well as qualitative or mixed-methods studies, using the same criteria, which was especially helpful when considering the diversity of the studies that were reviewed. The majority of studies fulfilled at least 3 of the 5 criteria for achieved good or high study quality. The results for those who did not score well were reserved for review and may have uncovered some information not reported by other studies and analyzed with due care. Studies that were coded to cluster A (mentoring & role models) received scores of 3 - 5 / 5, studies that were coded to cluster B (socio-cultural factors) received scores of 3 - 5 / 5, studies that were coded to cluster C (psychological & educational) received scores of 3 - 4 / 5, and studies that were coded to clusters D - E (workshops, curriculum, and barriers) received scores of 3 - 4 / 5. No study was excluded entirely on quality grounds, although lower-scoring studies are indicated in the synthesis, when applicable entirely on quality grounds, although lower-scoring studies are indicated in the synthesis, when applicable.

Three different research designs are used in the 19 studies reviewed: seven quantitative studies, seven qualitative studies and five mixed methods. In the present synthesis these sources of specific types of evidence are not treated as interchangeable but rather each one of these designs is given a specific role in the study analysis. Studies can be quantitative (e.g., Alam et al., 2021; Goreth & Vollmer, 2023; Lane et al., 2022; Stoeger et al., 2013) and can provide a measurement of the prevalence and size of gender differences, determine correlates associated with STEM participation, and estimate the effects of interventions. This makes their findings more likely to be accepted as evidence for the generalizability or frequency of phenomena. Qualitative studies provide richer contextual understanding of the mechanisms, lived experiences, and social processes that quantitative measures cannot fully capture (e.g., Almukhambetova & Kuzhabekova, 2020; Kinkopf & Dack, 2023; Millar et al., 2022; Mozahem et al., 2019). Their findings are preferred when interpreting how and why barriers operate in specific cultural settings. Mixed-methods studies (e.g., González-Pérez et al., 2020; Merayo & Ayuso, 2023; Reznik et al., 2023; Stoeger et al., 2023) are especially valuable for triangulating findings and exploring the relationship between measurable outcomes and contextual processes. Country of origin, sample size, and participant age group are also considered when interpreting study findings, since these factors moderate both the nature of barriers and the effectiveness of interventions across contexts.

Full search strings are documented in the Methodology section above. Screening was conducted independently by two researchers; disagreements were adjudicated by a third reviewer. The restriction to English-language publications may have introduced language bias; future reviews should adopt multilingual search strategies.

FINDINGS: DESCRIPTIVE OVERVIEW

Descriptive Information

The gender difference in STEM education studies raise a diverse set of issues to explore, as shown in the **Table 2**. The articles span the period between 2013 and 2023, reaching peak interest in 2019-2023, indicating an increasing focus of academic research on this issue. The studies cover a wide geographical area ranging from countries in Europe (Germany and Spain), North America (USA), South America (Brazil, Chile, and Uruguay), Asia (Malaysia, Hong Kong, Kazakhstan, and Lebanon), Africa (Zimbabwe and Tanzania) and Oceania (Australia). Such a global view shows clearly the worldwide importance of gender differences in STEM in a variety of cultural and economic contexts. The studies have been distributed between methodical approaches (quantitative studies, qualitative studies and mixed-methods studies) and arranged by three categories for each of the seven studies. The reviewed studies cover a range of problem points along the pipeline across various levels in STEM education, from early childhood through higher education and into workforce issues (Goreth & Vollmer, 2023; Martínez et al., 2023; Merayo & Ayuso, 2023; Sevilla et al., 2023b; Stoeger et al., 2023; Stone et al., 2013; Sullivan & Bers, 2019; Tenorio et al., 2023; Terrell et al., 2020; Tolbert, 2020).

Table 2. Descriptive information on studies

Thematic category	Authors (year)	Country	Methodology	Key focus
A. Mentoring & role models	Stoeger et al. (2013)	Germany	Quantitative	Online mentoring; STEM interest
	Guenaga et al. (2022)	Spain	Quantitative	Role models; technology attitudes
	González-Pérez et al. (2020)	Spain	Mixed methods	Role model intervention; math attitudes
	Stoeger et al. (2023)	Germany / international	Mixed methods	Long-term mentoring effects; career choice
	Millar et al. (2022)	Australia	Qualitative	Classroom environment; belonging; role models
B. Socio-cultural factors	Goreth and Vollmer (2023)	Germany	Quantitative	Technical socialization; gender and STEM interest
	Almukhambetova and Kuzhabekova (2020)	Kazakhstan	Qualitative	Cultural barriers; women in engineering
	Sevilla et al. (2023)	Chile	Qualitative	Gender identity; STEM persistence
	Reznik et al. (2023)	Brazil	Mixed methods	Intersectionality; informal STEM learning
	Martínez et al. (2023)	Spain	Qualitative	Gender role expectations; career perceptions
C. Psychological & educational	Kinkopf and Dack (2023)	USA	Qualitative	Self-efficacy; teacher influence; middle school
	Lane et al. (2022)	Australia	Quantitative	STEM motivation; gender differences
	Alam et al. (2021)	Malaysia	Quantitative	Self-efficacy; STEM participation
	Merayo and Ayuso (2023)	Spain	Mixed methods	Motivation; expectancy-value; gender
D. Workshops & curriculum	Sullivan and Bers (2019)	USA	Mixed methods	Engineering curriculum; female instructors
	Tam et al. (2020)	Hong Kong	Quantitative	STEM workshops; gender differences
	Tolbert (2020)	USA	Qualitative	STEM career awareness; aspirations
	Delgado et al. (2019)	Spain	Quantitative	ICT activities; geographic constraints
E. Structural barriers & pathways	Mozahem et al. (2019)	Lebanon	Qualitative	Structural barriers; engineering; family influence

Attitudinal variables of students towards STEM are examined in significant domains of inquiry, as well as mentoring and role model programs (Alam et al., 2021; Guenaga et al., 2022; Lane et al., 2022; Millar et al., 2022; Reznik et al., 2023; Stoeger et al., 2023). The number of publications with this output highlights the multi-discipline character of the problem as well as its occurrence in a large number of scholarly journals related to fields of the STEM disciplines, education, and psychology. All the evidence reflects the complexity around the gender gap in STEM and signals that there are various layers to addressing the gap – social, cultural, and educational – that require a complex strategy from multiple points in K-12 and professional learning environments. Analyses and research is international, so cross-cultural comparisons and the use of effective strategies in one context that are transferred to another is interesting.

Findings: Thematic Analysis

The results of the study are presented in **Figure 3**, i.e., in an overview of the results and in **Figure 4**, the individual category of results. Mentoring programs' effectiveness in reducing gender gap in STEM have been documented through empirical learning. Empirical studies have been reported extensively about the effectiveness of mentoring programs in addressing the gender gap in STEM and yielded promising findings. In Stoeger et al. (2023) the results showed a positive effect of the CyberMentor online mentorship program on the participants' life-long decisions regarding STEM. This influence remained long after they had completed the instructional session and affected their selection of a university major and career goal. The findings of Stoeger et al. (2013) suggests that the interest of women students in STEM field was successfully raised through use of the online mentorship program both in short term and in long term. The current investigation determined that there were differences between the mentorship group and control group in terms of their positive STEM development. The training reviewed in Guenaga et al. (2022) generated positive improvements on student attitudes towards technology and enhanced their knowledge of female scientists from academic areas of study in STEM. Further, it also boosted the image of science-related and information technology-related careers. However, the results of this program were not significant enough to achieve any real impact on changing the gender preconception and did not improve the mathematical self-efficacy of girls. This suggests that mentoring programs might help in some areas, but they may not be able to address issues such as sexism.

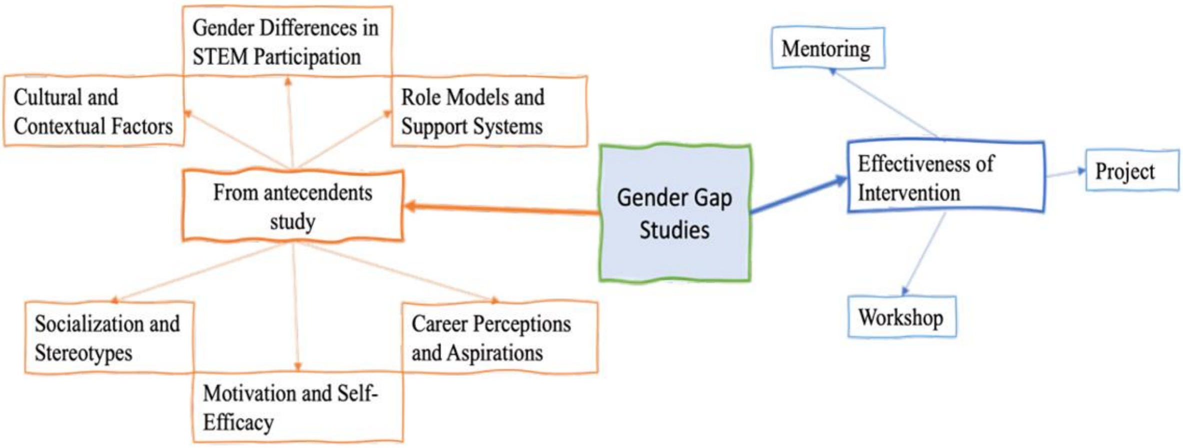

Figure 3. Overview of study results (the authors' own elaboration)

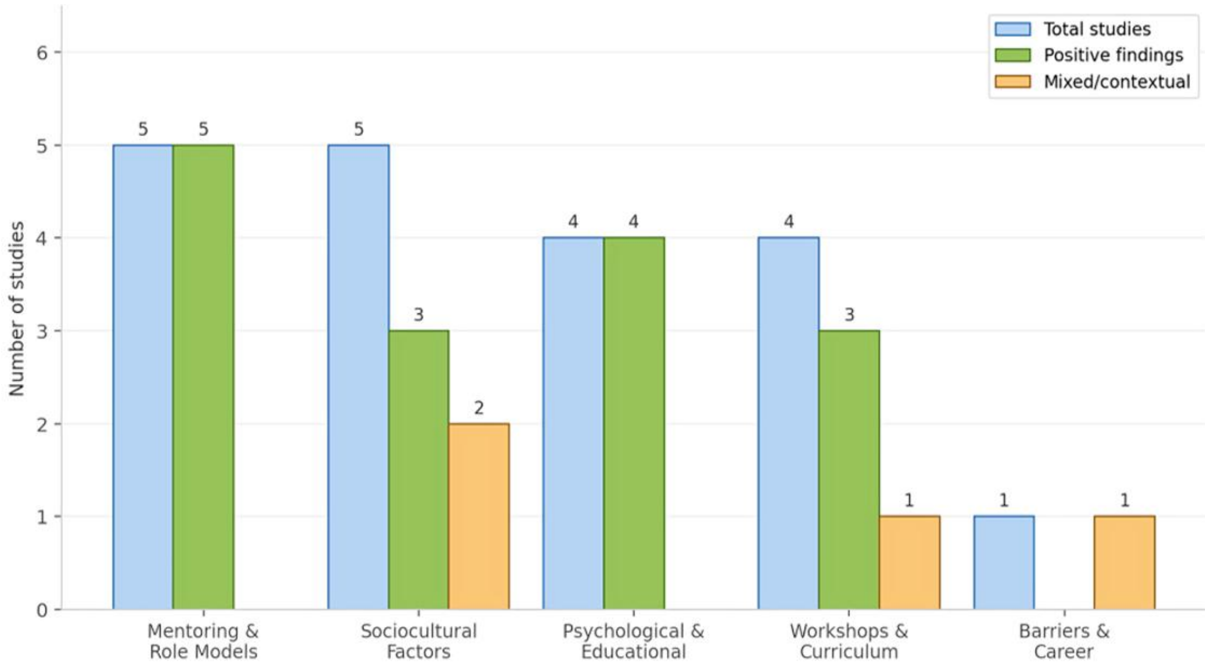

Figure 4. Overview of study results by thematic category (the authors' own elaboration)

Several studies have looked into the impact of the different workshops and curriculum courses that they develop to decrease the gender disparity in STEM studies and have yielded a number of interesting insights. The results presented here demonstrate the effects of workshops and curricular programs on increasing girls' interest and involvement in STEM areas.

As per reported results in Tam et al. (2020), the inquiry-based learning method led to students having significantly better abilities in solving problems and analyzing the matter. Implementation of this method helped to improve students' confidence in using ICT and at the same time reduced students' difficulties of using ICT. The study also indicated that encouragement of increased opportunities for ICT learning for female students has an impact on reducing gender stereotype of ICT. The results revealed that providing appropriate training techniques and opportunities can improve the feeling of self-confidence and technology skills of female students. Furthermore, the KIBO curriculum program (Sullivan & Bers, 2019) greatly increased the interest level of female students in the field of engineering. The presence of female teachers in this program can be said to positively impacted female students' interest in and academic achievement of robotics and coding. This is consistent with the observation noted by Delgado et al. (2019) that female teachers and role models entering the activities is effective in overcoming stereotypes and encouraging girls' interest in STEM fields.

The study examined a STEM career awareness workshop (Tolbert, 2020) which had a positive impact on the perceptions, awareness and aspirations of female students in STEM careers. This workshop provided females students with a view of them as STEM professionals and improved their knowledge and curiosity about STEM careers. This discovery is consistent with a greater interest of female students in these subjects, as checked by Delgado et al. (2019), that found strong demand for activities related to information and communication technologies (ICTs). However, the study which showed that there was a decline in the "figuring things out" cognitive framework (Sullivan & Bers, 2019) suggested that some educational activities, including LEGO activities, may negatively affect the confidence in the problem-solving skill of girls. Thus, attention must be given to the design of educational programs, and it is necessary to give priority to methods that allow for the learning of students of various learning styles and needs. Delgado et al. (2019) found geographic and financial barriers could hinder participation in STEM. The study emphasized the necessity of a policy to implement the various aspects of financial support that can be given to the transportation expenses for implementing the participation in these different geographical areas and maximize the participation. Furthermore, the finding that parental education level is related to the likelihood of their future children pursuing further education implies the need for an additional contribution of the family environment to ameliorate the gender gap in further education in STEM.

Overall, through this review of academic studies (Delgado et al., 2019; Sullivan & Bers, 2019; Tam et al., 2020; Tolbert, 2020), these interventions were found to have a significant impact on girls' interest and participation in STEM fields. But such efforts have to be done with caution in design and implementation, pushing back gendered stereotypes – such as role-models – and placing socioeconomic concerns at the forefront. An integrated approach may be useful in achieving more effective results in reducing gender disparity in STEM occupations.

The studies on various initiatives and interventions for the reduction of gender gaps in STEM support the importance of having a complex system of interventions, that is comprehensive (González-Pérez et al., 2020; Martínez et al., 2023; Reznik et al., 2023). These efforts statistically have positive outcomes for encouraging females' excitement and participation in STEM careers. The results reported in Reznik et al. (2023) underline the need to utilize a multi-factorial design that will incorporate individual, family, school, project, and social-level factors in the study of the experiences of young women that are encountered in informal scientific learning settings. This approach has been found to strengthen knowledge of the potential of such environments to create conditions for inclusion, equity and inclusion in research. The study showed to be effective that students' excitement and achieving good results in studying were enhanced by active involvement in projects especially in academic fields which is physics. The evidence made it clear, however, that young women frequently had fatigue and limited room in their daily schedules as a result of household chores, and the provision of care for family members. Thus, based on the present finding, it is essential to consider social factors in the development of STEM programs.

According to Martínez et al. (2023), the genders of youth and society are interwoven and form a persistent pattern. Gender commonly represented authors or technical jobs with boys, whereas care with females was commonly perceived as being within the realm of women. Empirical evidence suggested that girls were more likely to disagree with the idea of males being more able to do a STEM career than were men. The study suggested that the educational context is a significant contributor to choices made by youth in their STEM pathways, including a significant contribution to the gender pay gap, and there is a potential to make improvements in this area that could have a meaningful impact. Also, it is widely recognized that the male/female gender gap in this sector is a noteworthy issue, both nationally and internationally, offering with it some similarities between the different countries.

In the end, González-Pérez et al. (2020) found that there were positive outcomes of the role model intervention in nurturing females' excitement and appreciation for mathematics, understanding the importance of mathematics, feelings of success in mathematics, and aspirations for a career in a STEM-related college academic field. Furthermore, this intervention revealed a negative effect on gender stereotype indicating that women role models in STEM were effective in reducing gender stereotype. The study revealed a direct link between the amount of counter-stereotypical content in the instruction and mathematical career choice (anticipation of achievement) relationship. The above-mentioned discovery highlights the need to introduce a variety of less traditional role models and to take this measure if one wants to succeed in influencing career choices for girls.

Several of the key findings in these three studies (González-Pérez et al., 2020; Martínez et al., 2023; Reznik et al., 2023) reflect the necessity of a multifaceted strategy to decrease gender gap in STEM. There are several promising approaches that may decrease this gap, most notably the establishment of enhanced educational environments, additional practical applications, the use of role model treatments, and taking social factors into account. Moreover, it is crucial to commence these interventions throughout early child development and carry them out regularly. It is necessary to adopt this holistic approach to gender stereotypes reduction, to boost girls' self-efficacy views and to foster their interest in STEM areas. The results of the programs offer key data for policymakers, teachers and researchers when considering gender balance in the STEM classroom and as choices are made at the workplace.

Socializing and stereotypes strongly impact the gender disparity in STEM. Technical socializing is a key factor when dealing with the relationship between gender and STEM interests and confirming the hypothesized results of the study (Goreth & Vollmer, 2023). Research has shown that men more frequently exhibit multiple arenas of technical socialization, positively and significantly related to greater interest in STEM-related careers. This research coincides with (Merayo & Ayuso, 2023) which indicated that children's socialization environment (family and teachers) would have positively greater effect on boys' participation in the STEM activities compared to girls.

Stereotyping is one of the most highlighted issues in the participation of girls in STEM programs as described by Millar et al. (2022). These preconceptions stem from many origins, such as parents, teachers, classmates, career advisors, and the media, frequently causing girls to choose not to pursue STEM topics or possibilities. The study identifies situations of difficulty in the classroom, such as in senior year classes in mathematics and physics, where boys' behavior toward girls sends an unspoken message to girls about not expecting them to enter a career in STEM.

The authors of Sevilla et al. (2023b) examine preconceptions female faced in male-dominated STEM careers. The study indicated that the gender stereotypes, particularly the assumption that females are smaller and less physically capable than males heavily cost women who are preparing for jobs in these occupational areas. Nevertheless, there were certain empowering patterns in which women could break out of these stereotypes, so here the overlap of individual motivation with socialization and the role of stereotypes was emphasized.

Theme 1. Socio-cultural and institutional determinants of the gender gap

Social and cultural factors are the most frequently mentioned type of barrier in the reviewed studies, appearing in 10 of 19 papers. According to GST (Bem, 1981), these findings reflect deeply learned mental patterns that link STEM ability with being male and domestic roles with being female. These schemas are not individual but are socially transmitted through family socialization, peer interactions, media representations, and formal schooling. Critically, Goreth and Vollmer (2023) provide evidence from Germany that when technical socialization is controlled for, the effect of gender on STEM interest is substantially reduced—a finding that directly supports GST's prediction that STEM-gender associations are learned rather than innate. This has a direct practical implication: interventions targeting stereotype formation in early childhood may be more effective than remedial programs applied after schemas are deeply rooted.

A significant finding that cuts across cultural contexts is that the character and severity of sociocultural barriers varies substantially between societies, even if their direction is consistent. Almukhambetova and Kuzhabekova (2020) document that in Kazakhstan, official statistics record high rates of female STEM graduation, yet qualitative data reveal that women's experiences in engineering programs are marked by isolation, gender-based discouragement, and a persistent perception that technical fields are inherently male domains. This apparent paradox—quantitative parity alongside qualitative marginalization—is precisely what SCCT (Lent et al., 1994) predicts: formal access does not eliminate contextual barriers that suppress self-efficacy and outcome expectations. Similarly, Mozahem et al. (2019) find that Lebanese female engineering students navigate both institutional openness and deeply conservative familial expectations, producing ambivalence and attrition that enrollment statistics alone cannot capture. By contrast, Millar et al. (2022) in Australia and Goreth and Vollmer (2023) in Germany find that structural barriers are less pronounced but that subtle cultural messages—including classroom dynamics and peer interactions—continue to signal to girls that they are outsiders in STEM spaces. Together, these studies confirm that sociocultural barriers are universal in direction but highly variable in mechanism, which highlights the need for context-sensitive rather than universally applied interventions.

Beyond cultural attitudes, structural and institutional barriers compound sociocultural factors, and—critically—these barriers interact with other dimensions of social identity. Reznik et al. (2023) adopt an intersectional framework to demonstrate that girls from low-income and racialized communities in Brazil face compounding disadvantages: gender, class, and racial barriers do not operate independently but in mutually reinforcing ways, rendering the gender gap in STEM not a single phenomenon but a spectrum of qualitatively distinct experiences. This finding has direct implications for intervention design: programs that target gender in isolation, without accounting for the intersecting effects of socioeconomic status and ethnicity, are unlikely to reach those who face the greatest structural disadvantage. Riegle-Crumb and King (2010) similarly document that gender and race/ethnicity interact in complex ways in STEM trajectories in the USA—a finding corroborated across different national contexts in the reviewed sample. The synthesis of these intersectional findings suggests that future reviews and interventions should adopt an explicitly intersectional lens rather than treating gender as a singular or uniform variable. Martínez et al. (2023) document how gender-biased career guidance in Spanish secondary schools' channels girls away from STEM pathways before they can exercise genuine choice. Sevilla et al. (2023a) finds that even among girls who demonstrate strong STEM performance, gender identity norms create internal conflicts between academic aspiration and social conformity—a form of self-limiting actions consistent with EVT's cost dimension, whereby the perceived psychological cost of being a 'STEM girl' discourages pursuit of STEM even when capability and interest are present.

Theme 2. Psychological and educational pathways

Psychological factors—especially self-efficacy and motivation—are the second most common theme, addressed in 9 of the 19 reviewed studies. According to SCCT (Lent et al., 1994, 2000), these findings reflect the operation of the self-efficacy mechanism: girls who have social and cultural messages about gender and STEM develop lower self-efficacy beliefs, which in turn reduce their STEM career intentions irrespective of their objective ability. Alam et al. (2021) provide direct empirical support for this mechanism in a Malaysian context, documenting a strong positive correlation between self-efficacy and intention to pursue STEM education among female secondary students. Kinkopf and Dack (2023) extend this finding to an American middle school context, demonstrating that teacher-explained mastery experiences—a primary source of self-efficacy according to Bandura (1997)—are critical levers for improving girls' STEM self-efficacy at the developmental stage when career schemas are most changeable. This self-efficacy gap has proved remarkably persistent: a large-scale survey of secondary students in Madrid finds that girls report lower self-efficacy in physics and chemistry than boys with equivalent academic grades, indicating that the gap reflects confidence rather than competence (Brage-del-Río et al., 2025). Similarly, at the undergraduate level, female and gender-diverse students in introductory STEM courses report lower class-specific self-efficacy than their male peers, although supportive student-staff relationships and assessment practices that prioritize comfort with course material can narrow this gap (Lübeck et al., 2025).

The reviewed studies provide consistent support for EVT (Eccles et al., 1983; Wigfield & Eccles, 2000). Merayo and Ayuso (2023) find that while Spanish girls and boys show comparable STEM performance, girls assign significantly lower attainment value to STEM subjects—that is, they regard STEM as less central to their self-concept—a finding that EVT attributes to gender-differentiated socialization rather than ability differences. Sevilla et al. (2023a) identifies utility value differences: girls are more motivated by the prosocial utility of STEM (helping others, contributing to society) while boys prioritize financial and competitive incentives. This difference shows that STEM education and communication that focuses on prosocial applications—medicine, environmental science, social technology—may more effectively engage girls' existing value structures without requiring them to abandon their gender identities. Lane et al. (2022) provides corroborating Australian evidence, finding that gender differences in STEM confidence and encouragement—key determinants of expectancy—are sustained across school years and do not diminish without deliberate intervention.

At the educational-environment level, the reviewed studies consistently identify classroom dynamics as critical mediating contexts. Millar et al. (2022) conduct a qualitative investigation of senior-year physics and mathematics classrooms in Australia, finding that these environments can function as hostile social spaces for girls through the operation of peer ridicule, teacher unequal treatment, and the spatial dominance of male students—all of which compound stereotype threat effects (Steele & Aronson, 1995) that suppress girls' performance and identification with STEM. These findings are consistent with SCCT's emphasis on contextual supports and barriers: the classroom is not a neutral environment but an active social context that either reinforces or undermines girls' STEM self-efficacy. The implication is that teacher training in gender-responsive pedagogy is not merely desirable but necessary to create classroom conditions in which girls' STEM self-efficacy can develop.

Theme 3. Role models, mentoring, and intervention effectiveness

The reviewed evidence on interventions points to several types of programs with positive effects on girls' STEM engagement, though the strength and durability of evidence varies substantially across intervention types. The strongest evidence base belongs to the CyberMentor online mentoring program studied longitudinally by Stoeger et al. (2013, 2023). The 2013 study demonstrated positive short-term effects on girls' STEM interest and self-efficacy; the 2023 follow-up is the only study in the reviewed sample to document lasting effects on actual career choice, with cybermentoring participants significantly more likely to have entered STEM careers at ten-year follow-up. According to SCCT, the cybermentoring program works precisely because it provides female mentors who serve as vicarious learning models (demonstrating that women can succeed in STEM), builds outcome expectations through mentored goal-setting, and creates a sustained contextual support structure that counteracts environmental barriers over time. The continuing relevance of mentoring is echoed in more recent qualitative work: interviews with women in managerial, research, teaching, and external professional STEM roles describe mentoring as a role-responsive process whose value—emotional support, skill development, or leadership confidence—shifts according to the mentee's career stage, suggesting that mentoring programs are most effective when intentionally tailored rather than generic (García-Silva et al., 2025). A multi-study evaluation in Mexico similarly finds that combining female-empowerment mentoring with structured male-allyship initiatives can more effectively sustain women's interest and persistence in STEM than mentoring alone, particularly for students from socioeconomically disadvantaged communities (Burgos-López et al., 2025).

Prior background research documents consistent positive effects of role model interventions on girls' STEM attitudes, academic performance, and outcome expectations (Herrmann et al., 2016). González-Pérez et al. (2020) find that exposure to non-traditional female STEM role models—women who violate the dominant stereotype of STEM as a masculine domain—produces significant improvements in girls' mathematics attitudes and career openness. A recent large-sample randomized controlled trial in Spain reinforces this evidence base: a single brief video exposing adolescents to a relatable female mathematician significantly improved perceptions of mathematics as practically useful and increased mathematics-related career aspirations, with the gains in career aspirations concentrated among girls, even though the intervention had no measurable effect on explicit beliefs about innate gender differences in mathematical ability (Osés & Martinez de Lafuente, 2025).

Guenaga et al. (2022) demonstrate positive effects on technology attitudes and perceptions of STEM careers in a Spanish secondary school sample, though the same study found no significant changes in gender stereotypes or girls' mathematics self-efficacy—a finding that underscores the domain-specificity of attitude change and the difficulty of dislodging deeply rooted stereotypes through single-intervention exposure. Consistent with STT (Steele & Aronson, 1995), the mechanism for the observed positive effects appears to operate through stereotype reduction in the targeted domain: seeing women succeed in STEM undermines the situational cue that activates stereotype threat, creating a safer learning environment for girls to engage with STEM content. However, a critical limitation of both studies is the absence of long-term follow-up data: it is unknown whether positive attitudinal changes translate into sustained STEM participation. This represents the primary gap in the intervention evidence base.

Workshop-based and curriculum interventions show promising but more varied effects. Sullivan and Bers (2019) demonstrate that an engineering curriculum taught by female instructors in American preschool and early elementary settings produces significant improvements in children's engineering task performance with no gender gap, suggesting that very early intervention—before gender schemas are consolidated—may be particularly effective. Supporting this, background research by Oppermann et al. (2019) demonstrates that preschool teachers' science self-efficacy beliefs directly shape early science teaching

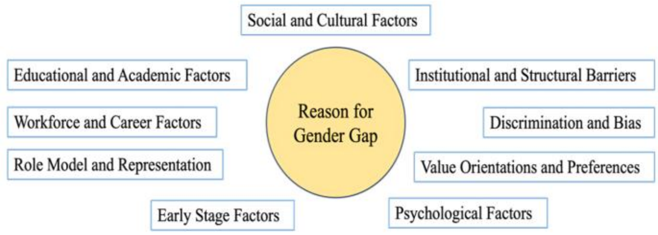

Figure 5. Representations of reasons for gender gap in STEM (the authors' own elaboration)

quality and girls' and boys' early science motivation, underscoring the critical role of teacher preparation at the earliest educational stages. Tam et al. (2020) find positive effects of STEM workshops on interest and confidence among Hong Kong secondary students, though effect sizes are modest and the absence of a control group limits causal inference. Tolbert (2020) documents improvements in STEM career awareness and aspiration among American middle school girls following a dedicated STEM career program, with qualitative data indicating that girls began to envision themselves as future STEM professionals. Delgado et al. (2019) note that participation in ICT activities was constrained by geographic and financial access barriers, underscoring that well-designed interventions may fail to reach those most in need if structural access barriers are not simultaneously addressed.

One important limitation across all three types of interventions is that most studies use pre/post designs without a control group, and very few include long-term follow-up. Among the 7 quantitative studies, only the Stoeger longitudinal program (Stoeger et al., 2013, 2023) provides longitudinal evidence of lasting effects on career choice. The other studies rely on cross-sectional or short-term designs, which make it difficult to draw conclusions about the lasting impact of interventions. This is a significant gap in the evidence, especially given that the reviewed studies consistently show that early childhood and adolescence are the most important periods for shaping STEM interest and confidence (Eccles & Wang, 2016; Sullivan & Bers, 2019). Future research should include longer-term studies that track the effects of early STEM programs through secondary school, university, and into the workforce.

Figure 5 and **Figure 6** presents a thematic map of the reasons for the gender gap in STEM as identified across the 19 reviewed studies in detail. The visual representation reveals that social and cultural factors constitute the most frequently cited category, appearing in 10 of 19 studies (Almukhambetova & Kuzhabekova, 2020; Delgado et al., 2019; González-Pérez et al., 2020; Goreth & Vollmer, 2023;

DISCUSSION

This systematic review uncovers the multifaceted make-up of the gender gap in STEM. The discussion has

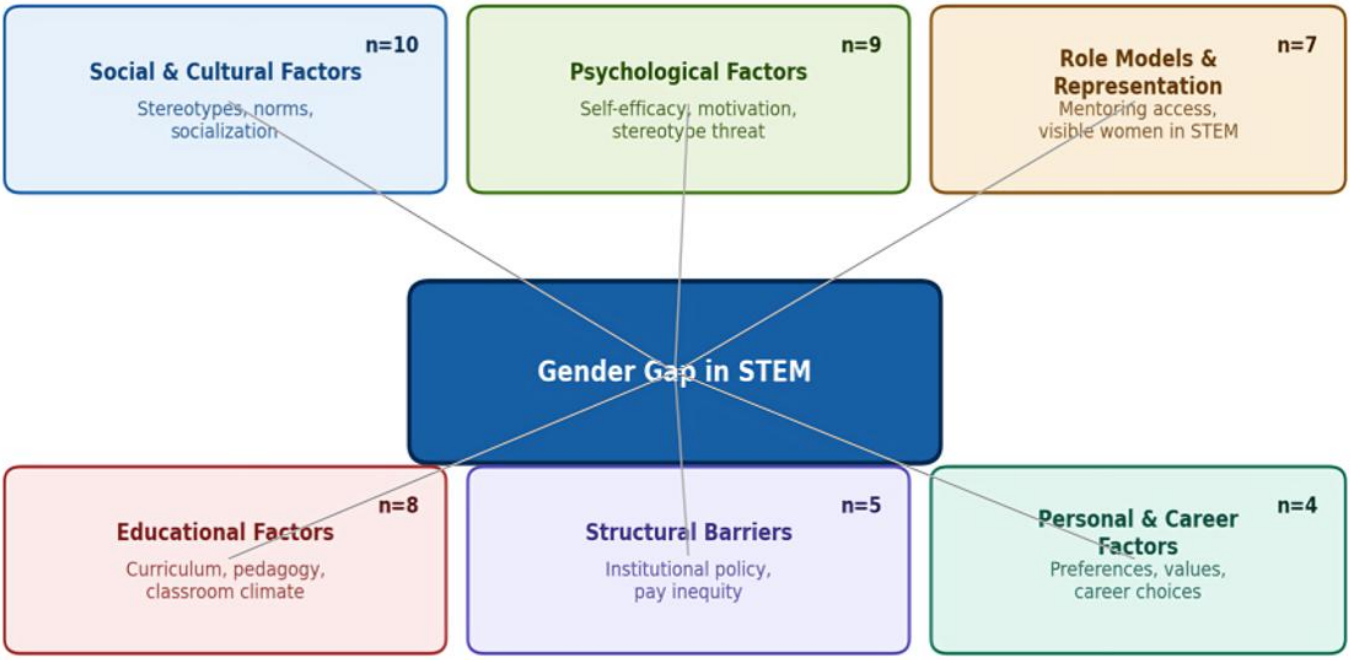

Figure 6. Frequency of citation across 19 reviewed studies (n: number of studies citing each theme) (the authors' own elaboration)

been organized according to our research questions. Out of all the studies considered, the majority of them are published in the last five years (2018-2023), mainly focusing on the most recent years. This is because of its topicality and the increasing academic interest. Have a wide range of distribution and occurrence reported from across Europe to North and South America, and across Asia, Africa, and Oceania. From this international vantage point, there is agreement that there is a general STEM "gender problem" (Stoet & Geary, 2018).

From a methodological point of view, the works analyzed found a majority of qualitative, quantitative and mixed methods approaches used as a research methodology tools to analyze the gender gap in a complementary manner. Qualitative studies provide clues about how barriers function in some social context and quantitative research can provide a better estimate of prevalence and correlates of gender disparities. The variety of geographical coverage of the studies (Germany, to Spain, Malaysia, Lebanon, Kazakhstan, Australia, Ireland, Tanzania, and elsewhere) allows them to be compared by culture to discuss different topics.

Empirical evidence confirms that women remain significantly underrepresented in STEM disciplines, with particularly pronounced gaps in computer science and engineering (Sassler & Meyerhofer, 2023). Concurrently, the reviewed studies provide evidence that targeted interventions can meaningfully improve female students' engagement and participation. Mentoring programs emerge as especially effective: Stoeger et al. (2023) document that online mentoring produces durable effects on girls' STEM career choices—a finding consistent with the broader literature on mentoring as a lever for gender parity in STEM (Dennehy & Dasgupta, 2017). Early STEM education also shows clear benefits: Sullivan and Bers (2019) demonstrate that engineering curricula delivered in early childhood, particularly by female instructors, can eliminate gender differences in engineering task performance. This aligns with Master et al. (2017), who document that early exposure to STEM role models and curricula is among the most effective strategies for closing gender gaps. A PRISMA-guided meta-analysis aggregating effect sizes across gender-equity interventions in STEM education corroborates this picture at scale, reporting a near-medium overall effect (Hedges' $g = 0.434$) that varies significantly by intervention type, country, and educational level, although not by the type of outcome measured—evidence that the heterogeneity documented across the present review's 19 studies reflects a genuine, generalizable pattern rather than an artefact of this particular sample (Yu et al., 2024).

The reviewed studies converge on a set of interacting causal factors—gender stereotypes and sociocultural norms associating STEM competence with masculinity, self-efficacy deficits, limited access to female role models and mentors, and institutional barriers—that do not operate independently but interact in compounding ways across developmental stages. Concurrently, the analysis confirms that structured interventions, including mentoring programs, workshop-based curricula, and role model exposure, demonstrate positive short-term effects on girls' interest, confidence, and STEM career aspirations, though the durability of these effects beyond the immediate intervention period remains insufficiently documented.

Among the intervention strategies supported by the reviewed evidence, early STEM exposure at primary level and sustained mentoring programs emerge as the most consistently effective, with the former acting preventively on stereotype internalization and the latter providing the psychosocial and identity support that helps women persist in STEM beyond initial engagement. Critically, no single intervention type is sufficient in isolation; the evidence points consistently to the need for multi-level, coordinated approaches.

Another advised approach is enhancing curricula and instruction techniques (Tam et al., 2020; Tolbert, 2020). This corresponds with earlier research stressing the need for inclusive pedagogy in STEM education (Rainey et al., 2018). Suggested are also institutional policy reforms (Martínez et al., 2023). This finding is consistent with recent studies demonstrating that systematic reforms are required to advance gender parity in STEM (Charlesworth & Banaji, 2019)

In sum, this review demonstrates that the gender disparity in STEM education is complex and dynamic, sustained by the interaction of cultural, psychological, educational, and structural forces. Closing this gap requires coordinated, evidence-based action operating across multiple levels: expanding role model access, implementing sustained mentoring, challenging stereotypes through curriculum reform, and establishing inclusive institutional policies. The integrated theoretical framework—drawing on SCCT, EVT, STT, and GST—provides the conceptual scaffolding for interpreting this evidence and designing future intervention.

Across the reviewed studies, several important tensions and contradictions emerge that deserve analytical attention beyond the descriptive aggregation of findings. First, there is a tension between the documented effectiveness of individual-level interventions—such as mentoring programs and role model exposure—and the structural persistence of institutional and cultural barriers. While Stoeger et al. (2023) and Guenaga et al. (2022) demonstrate positive effects of mentorship on girls' STEM interest, the effects appear to be subject-specific and short-term in some cases, failing to translate into lasting changes in gender stereotypes or mathematical self-efficacy. This suggests that individual-level interventions, however well-designed, are insufficient in the absence of complementary systemic and cultural change. Second, contradictions emerge across cultural contexts: studies from highly gender-equal societies (e.g., Germany in Goreth & Vollmer, 2023) demonstrate that technical socialization—rather than gender per se—explains STEM interest, implying that removing cultural barriers may be more effective than targeted gender interventions. By contrast, studies from more gender-stratified societies (e.g., Kazakhstan in Almukhambetova & Kuzhabekova, 2020; Lebanon in Mozahem et al., 2019) find that structural and cultural barriers are so pronounced that individual-level interventions have limited effect without broader social change. These contrasting findings have significant implications for the transferability of interventions across contexts, a point that has received insufficient attention in the literature.

A further constraint on previous research is the focus on short-term single group studies. The 7 quantitative studies reviewed only include 2 studies with follow-up data over time that found a lasting impact on career choices following STEM programs (Stoeger et al., 2013, 2023). Other studies are based on pre-post studies or cross-sectional surveys, methods not sufficient to demonstrate the developmental and dynamic process of building STEM identity and the development of career aspirations. The methodological gap is especially relevant when considering how the evidence reviewed uncovered early childhood and adolescence as crucial time periods for intervention (Eccles & Wang, 2016; Sullivan & Bers, 2019). It is thus necessary to conduct well-designed longitudinal studies tracking the impact of early STEM interventions through secondary and tertiary schooling and on the labor market. In addition, the analysis shows that there is little effort to determine gender gap in particular STEM fields and not in STEM as a whole category. Gender gaps vary in both size and shape across domains such as computer science, in which some instances the gap has attained larger size; biological sciences, in which women might reach parity to exceed it in some instances; and engineering, in which it reflects past gender dominance. An examination of each specific discipline of STEM is necessary to design specific interventions.

The methodological strength of the studies reviewed is highly variable, and the smaller their sample size and different their research designs, the more variable their interpretations of the results. These differences in methodological rigor, sample size and type of research design should be reflected in the weight given to results. Qualitative case studies provide useful information on effect sizes and prevalence to small populations, whereas quantitative studies have larger representative samples and provide more reliable estimates of effect sizes and prevalence, such as in the works of Goreth and Vollmer (2023) and Lane et al. (2022). On the other hand, quantitative studies can only measure something that qualifies studies like Almukhambetova and Kuzhabekova (2020); Mozahem et al. (2019) demonstrate in more detail the different mechanisms behind it. These designs should be used together: quantitative studies to confirm the gender gap and how it correlates; qualitative studies to understand how and why barriers are operating in their social setting. There is a need to respect this complementarity in the present synthesis, although it might prove useful to use a formal synthesis method in the next review, such as realist synthesis (Pawson et al., 2005) or Bayesian updating which is able to synthesize evidence of other types and qualities in a structured manner.

The results of this review; examined using the lens of the theoretical framework outlined in the introduction, suggest a consistent pattern: that the gender gap in STEM learning is the result of a complex interplay of multiple mutually reinforcing processes that occur at the level of the individual, interpersonal actions, and the structure. The evidence shows that from an SCCT standpoint, self-efficacy deficits will be a direct route to lower rates of STEM participation, at least in part due to stereotype internalization, and in part due to differential experiences of mastery, which is in turn linked to differential experiences of role models. Gender differences in tasks' value attribution, specifically lower value for STEM amongst girls, influence course choice and continuation in part other than performances, from an expectancy-value standpoint. Both STT and GST help explain how such open-ended learning environments as STEM might become psychologically closed to women.

It is also well established from the reviewed studies that gender alone is not reflective of the gender gap in STEM. A number of studies show that many gender differences exist between the experiences of various groups of women, depending on race, ethnicity, socioeconomic status and location. Like other Western nations, such as Norway (Krogvik et al., 2020) or the Netherlands (Tkula et al., 2022), these women and girls experience overlapping disadvantages (Reznik et al., 2023); they are also isolated in the face of conservative gender norms or encountered with ambivalence in the context of education – reasons they are made up and reported by their families – as in the case of women studying engineering in Kazakhstan (Almukhambetova & Kuzhabekova, 2020) or leading the Lebanese women engineers (Mozahem et al., 2019). This suggests that interventions with no consideration for the intersectional context may be ineffective if not harmful to the most marginalized—attempts to do better will have a detrimental impact if not to those groups, then to the universal poor outcomes they will achieve.

The reviewed studies highlight various contradictory aspects that warrant analysis. First, in more gender-equitable contexts, e.g., Germany, Australia, studies reveal that explaining STEM interest is more related to technical socialization than to gender identity itself (Goreth & Vollmer, 2023; Millar et al., 2022); this suggests that it may be more effective to decrease stereotypic socialization than to target gendered intervention. In contrast, the other studies conducted in countries with more gender segregated population trends in educational attainment, such as Kazakhstan and Lebanon, have found feminizing influences to be so entrenched that trends in personal empowerment will not affect the system unless it is fundamentally changed. The contextuality of this is very important but has not been explored often enough – that is, if one knows one model of children's interventions, it is not necessarily directly transferable across cultural contexts. Future reviews need to explicitly cross-nationally compare, in order to determine those elements of the intervention that are context-specific and those that are culturally universal.

The synthesis of evidence across the reviewed studies points toward a multi-level integrative model of intervention. As illustrated schematically, this model operates across four interconnected levels: (level 1) early socialization and education (preschool to primary school)—the period before gender schema formation becomes entrenched—where exposure to diverse STEM role models and inclusive curricula can prevent stereotype internalization; (level 2) targeted psychological and motivational interventions at secondary school level, a developmental period of heightened risk for STEM disengagement, focused on self-efficacy building and value alignment via prosocial STEM framing; (level 3) sustained mentoring and role model programs spanning secondary and tertiary education, supported by longitudinal contact and career guidance; and (level 4) systemic institutional and policy reform—including gender-inclusive hiring, transparent promotion pathways, and anti-discrimination mechanisms—that creates the structural conditions within which lower-level interventions can take effect. This integrative model extends existing single-level frameworks by treating individual psychological change, interpersonal support, and structural reform as mutually dependent rather than independently sufficient. Partial empirical support exists for each component in the reviewed studies; however, no study evaluated all four levels simultaneously, representing the most important gap identified in this review and the primary direction for future research investment.

The geographical distribution of the reviewed studies is weighted towards Western Europe (Germany and Spain), North America (USA), and select Asian and Latin American contexts. Notably, no studies from Nordic countries (Denmark, Finland, Norway, Sweden, or Iceland) met the inclusion criteria, despite these countries' extensive track record of research on gender equality in STEM and their consistently high scores on the global gender gap index. This absence reflects the operation of the search and inclusion criteria rather than a normative judgment about the quality of Nordic research; it is likely attributable to the dominant indexing of English-language publications in Scopus and WoS and to the fact that some Nordic research is published in national-language journals not captured by these databases. The so-called gender-equality paradox—the counterintuitive finding that women's STEM representation is lower in more gender-equal societies (Stoet & Geary, 2018)—remains methodologically contested and should be interpreted with considerable caution. The absence of Balkan and

Central and Eastern European studies constitutes a further geographical gap. Future systematic reviews should explicitly incorporate multilingual search strategies and include regionally specialized databases to ensure more equitable geographic coverage and strengthen the generalizability of findings found in English and Western European languages. In subsequent reviews, it would be beneficial to expand searching to regional journals and non-English journals and databases to provide a more equitable geographic coverage.

Taken together, the four theoretical frameworks—SCCT, EVT, STT, and GST—converge on a coherent and compelling account of the gender gap in STEM education. Gender-differentiated socialization produces asymmetric task value attributions; these in turn suppress girls' self-efficacy beliefs; stereotype threat then further undermines performance and identification with STEM; and these individual-level processes are reinforced and perpetuated by structural and institutional barriers that fail to counteract them. None of these factors can be attributed as single causes of the gap; it is the interplay at each developmental phase and across social settings that leads to the enduring under-representation of women in STEM. Knowing about multiple levels has practical implications: working at these multiple levels has to happen at the same time, starting in early childhood, moving to the middle school level, secondary and post-secondary education, and then systemic changes in culture and policy.

Recommendations to Decrease Gender Gap in STEM

One thing that remains clear in all of the studies examined is that early education has a significant impact on the engagement of girls with STEM. There are some indications that exposing early childhood and primary-school students to STEM concepts fosters inquiry, confidence in self-efficacy, and decreases the impact of gender stereotypes before they are entrenched (Mérida-Serrano et al., 2020). One of the most common strategies to make curricula more gender responsive is to design learning environments that are responsive. Curriculum responsiveness is one of the most common recommendations that can make curricula more gender-responsive. The continued relevance of this recommendation is underscored by recent evidence from Saudi Arabia showing a positive and significant correlation between girls' STEM self-efficacy and their interest in STEM careers, with medicine emerging as a particularly strong draw—a reminder that career-relevance framing, not only confidence-building in the abstract, should be built into curricular design (Yamani & Almazroa, 2024).

It is not surprising that this is one of the recommendations that concerns female representation, since it is one of the main pillars for its centrality in STEM. Structured mentoring programs bring successful women scientists volunteer together to feed the minds of young women in the science, technology, engineering and math domains, peer support networks empower young women, and regular exposure to non-traditional role models help to reshape their minds. Stoeger et al. (2013, 2023) offer the best evidence for the lasting impact of online mentoring.

The majority of the reviewed studies (14 of the 19) highlight the need for tackling entrenched gender stereotypes as a necessary step for successful STEM intervention. Examples of recommended practices are teacher and guidance counsellor professional development to reduce implicit gender bias; implementing curriculum changes to diversify the portrayal of women in learning materials related to STEM; and parental education campaigns to raise awareness about the parents' role to support female STEM interests, even if they are not the cultural norm.

An important tactic is a change of course(s) and teaching styles to cater to inclusion. Some suggestions include gender-inclusive course development (Merayo & Ayuso, 2023), emphasizing experimentation in the use of active learning (Reznik et al., 2023), and adoption of the inquiry learning model (Tam et al., 2020). The recommendation for integrating arts into STEM, because this helps boost interest (Tolbert, 2020), indicates an understanding that using a multidisciplinary approach might be more interesting in terms of getting the engagement of a student body with various backgrounds.

It was recommended in many of the articles that being psychologically safe and inclusive when in a learning environment is a continuous loop. This includes creating learning environments that embody a culture that respects and cares for girls, tackling the system-level discrimination in how they are assessed and included, and implementing a positive sequence of learning policies and culture throughout the STEM career pathway that recognizes and supports the various life experiences of women in STEM.

STEM-based experiential learning is always evidenced to boost interest and persistence by female students. Out of school STEM enrichment programs, industry internships, maker space programs, and targeted STEM curricula that bring girls meaningful and authentic experiences in STEM practice are recommended strategies.

It is acknowledged that institutional and policy level change is required to complement individual and educational change. Specific actions include gender-inclusive institutional policies, parity of opportunities for hiring and promotion and transparency-based pay equity mechanisms, and a policy to support women in the workplace in order to strengthen the retention of women along the STEM career pathway.

Figure 7. Recommendations decreasing gender gap in STEM (the authors' own elaboration)

An intervention target that is identified as a high priority is building self-efficacy and a growth mindset among female STEM students. Evidence-based recommendations include mastery-oriented instruction with incremental challenges and feedback; emphasizing effort and persistence over natural ability; and structured activities (e.g., peer tutoring, competition, and research involvement) that support authentic experiences of mastery.

Engaging family and communities as a part of issues related to gender equity in STEM education is recognized as a significant yet often overlooked dimension. Aligned with these, reviewed studies suggest that deliberate communication campaigns addressing the issue of gendered socialization, involvement of civilians and industry groups in promoting girls' participation in STEM and collaborative relationships between schools and industry and civil society that shape long-term shifts in norms.

Several research reports reviewed recommend the promotion of STEM career paths to women. Examples of effective strategies involve showcasing the social impact and prosocial utility of STEM careers, emphasizing the economic benefits and diversity of STEM pathways, and creating bridge programs to bring girls to STEM professionals whose values match their own and their interests (**Figure 7**).

CONCLUSION

Results for this systematic review reveal that the gender gaps in STEM education is a multifaceted issue, influenced by a myriad of factors contributing to the gender gaps in STEM fields. The systematic analysis of 19 empirical studies published between 2013 and 2023 identified the structural, sociocultural, psychological, and educational causes of the gender gap in STEM, evaluated the effectiveness of existing interventions, and generated evidence-based recommendations for future research and practice. Our results indicate that the gender disparities in STEM are a combination of a range of social, cultural, educational and psychological issues. Some significant causes of the lack of women in STEM fields are gender stereotypes, perceptions of self-efficacy, inadequate role models, and institutional barriers. These factors play a role in shaping a female student's interest and participation in STEM at a young age and carry over in higher education and career pathway decisions. The reviewed studies looked at the impact of a range of interventions on closing the gender gap. There is evidence of the success of mentoring programs, early STEM education and the programs of role-models on addressing stereotypes. Specifically, the study found that, in this situation, mentoring programs provided through the internet and opportunities for hands-on, experiential work in STEM subjects were effective in increasing girls' engagement and interest in STEM gender disparities in STEM are a combination of a range of social, cultural, educational and psychological issues. Some significant causes of the lack of women in STEM fields are gender stereotypes, perceptions of self-efficacy, inadequate role models, and institutional barriers. These factors play a role in shaping a female student's interest and participation in STEM at a young age and carry over in higher education and career pathway decisions. The reviewed studies looked at the impact of a range of interventions on closing the gender gap. There is evidence of the success of mentoring programs, early STEM education and the programs of role-models on addressing stereotypes. Specifically, the study found that, in this situation, mentoring programs provided through the internet and opportunities for hands-on, experiential work in STEM subjects were effective in increasing girls' engagement and interest in STEM.

Based on the findings of this analysis, a holistic and long-term approach will need to be taken to reduce the gender gap in the STEM fields. The previous section on Recommendations outlines the evidence-based recommendations developed in this review that include early intervention; programs using role models and mentoring; stereotype challenging programs; programs to reform the curriculum; programs to change institutional policy; and programs to engage family/ community.

The present systematic review is subject to many limitations. The first one was that the review only focused on English language papers, which may exclude other-language papers that could have some important findings. Second, the most of the studies reviewed were conducted in the developed country (Global North) limiting the applicability of findings to developing countries (Global South). Third, almost all the studies on short term interventions, thus making the assessment of long-term effects difficult. Indeed, the assessed studies have methodological differences that may influence the reliability of some of the findings. Fourth, interrater reliability data was not computed for the coding process; disagreements were discussed, but since no coefficient of reliability was used (e.g., Cohen's kappa), the reliability coding procedure is not transparent. Fifth, this review was not systematic review pre-registered on a systematic review registry, which limits the protection against reporting outcome bias—this should be done for future reviews on this topic. Lastly, several included studies (especially Stoeger et al., 2023 and González-Pérez et al., 2020) examine some career-orientation outcomes that fall into the domain of workplace and industry contexts that were not specified by the search query, those studies were included because the underlying theme of the educational experiences and STEM persistence were still in focus, but it is important for readers to be aware of these edge cases.

Recommended Areas for Further Investigation

This paper presents the following recommendations for future research:

1. Long-term, longitudinal analysis: Further longitudinal studies are necessary to assess the enduring impacts of STEM programs.
2. Intersectionality focus: Research is required to investigate the impact of several identity elements, including gender, race, ethnicity, and socioeconomic position, on STEM involvement.
3. Additional study should be undertaken in developing nations to have a comprehensive understanding of the mechanisms of the gender disparity in STEM within diverse cultural and economic settings.
4. Comparative analysis of intervention programs: Enough investigation should be done to assess the relative effectiveness of several forms of interventions.
5. Increasing qualitative research should be done to help to clarify women's experiences in STEM and therefore foster a deeper awareness of them.
6. Policy assessments: Studies should be conducted to evaluate the effectiveness of programs aiming at the progress of women equality in STEM.

In conclusion, this systematic review highlights the necessity of implementing a comprehensive and sustained strategy to reduce gender disparities in STEM fields. Sustainable progress toward gender equity in STEM will require coordinated action, long-term institutional commitment, and coordinated reform across educational, cultural, and policy domains. This objective not only relates to personal professional opportunities but also to fairly spreading the advantages of scientific and technological advancement to the whole population.

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