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Obstacles and Supporting Factors for Women in Software Engineering Education and Professional Work: A Literature Review

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Abstract: Despite progress in gender equality across many disciplines, women remain significantly underrepresented in software engineering. This imbalance is not only a question of fairness, but also a limitation on diversity of perspectives, creativity, and innovation in the field. This review paper examines the barriers women face and the factors that can support their participation and success across two key contexts: higher education and the professional work environment. Drawing on foundational and recent literature, the paper identifies recurring challenges such as gender stereotypes, limited role models, biased evaluation practices, reduced sense of belonging, and unsupportive organizational cultures. At the same time, it highlights supportive practices associated with improved participation and persistence, including inclusive pedagogy, pair programming, mentorship, flexible working conditions, and inclusive team and workplace climates. The findings suggest that women's participation in software engineering is shaped by interconnected individual, interpersonal, and structural factors, and that meaningful progress requires coordinated interventions across educational and professional settings.

Keywords: Computer programming, Software engineering, Educational technology

Introduction

Software engineering is one of the most dynamic and influential fields today, driving technological innovations that shape the economy and society. Despite its importance and the constant demand for experts, a significant gender disparity persists in this sector. Historically, women played a key role in the development of computer science, yet today they are significantly underrepresented, both in the educational system and on the labor market in the field of software engineering.

This underrepresentation is not just a statistical indicator but a problem with profound consequences. By limiting the diversity of teams, the industry loses access to a broader spectrum of ideas, problem-solving approaches, and innovative solutions. On the other hand, women face obstacles that hinder or prevent their entry and career advancement, thereby limiting their professional opportunities. Understanding the causes of this problem is an important step toward creating a more equitable and productive environment.

Beyond representation, gender diversity can shape what problems are prioritized and how software is designed, evaluated, and maintained. In software engineering, choices made during requirements engineering, user-experience, design, testing, and quality assurance influence real users and may reinforce bias when teams lack diverse perspectives. For that reason, the question of women's participation is not only about increasing headcount, but also about improving socio-technical outcomes such as accessibility, fairness, and long-term sustainability of systems. In this review, obstacles and supports are therefore interpreted across multiple levels: individual (e.g., self-efficacy), interpersonal (peer culture, mentoring networks), and institutional (curriculum

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structures, hiring and promotion systems) to connect research insights to interventions that educators and employers can realistically apply. This literature review is focused on synthesizing existing scientific knowledge to answer the following research questions:

RQ1 - What are the key obstacles that female students and/or employees face in: (a) the educational and (b) the professional domain related to software engineering?
RQ2 - What factors can have a positive and supportive impact on the more successful participation and achievement of women in the areas of: (a) education and (b) practical work related to software engineering?

Method

For the purposes of this literature review, publications from several different sources were searched, including Google Scholar, IEEE Xplore, Web of Science, and Scopus. Various descriptive queries were used, combining keywords such as "software engineering," "computer programming," "women," and "education." The search strategy also included variations of these keywords and the use of Boolean operators to ensure the breadth and relevance of the retrieved papers (Garcia-Alvarado & Ordonez, 2010).

The inclusion criteria focused on papers dealing with the experiences of women or gender differences primarily in the context of higher education and/or professional work in software engineering, with an emphasis on software engineering. No time frame was initially set, and the papers had to be in English. After an initial search that yielded a large number of potential sources, a two-stage selection process was applied. First, a review of titles and abstracts was conducted to identify those relevant to the research questions (RQ1 and RQ2). Papers not focused on the experiences of women or gender differences in the context of education or practice, or those dealing exclusively with technical aspects without a social or gender dimension, were excluded from further analysis. In the second phase, the papers that passed the initial selection were reviewed in full.

The final criteria for inclusion in this literature review were: a) thematic relevance-the paper directly addresses obstacles and/or supporting factors for women in higher education or a professional career in software engineering, and b) context-the paper's focus is primarily on higher education and/or the professional work environment. Papers dealing exclusively with primary or secondary education were included only if they provided direct context for the research questions.

Following these two phases, a final set of papers was defined with the aim of providing a representative and balanced overview of key findings in the field, directly answering the research questions. Papers were selected that cover various aspects of the identified obstacles and supporting factors, in both educational and work contexts. Preference was given to papers published in relevant and recognized journals and conferences (e.g., Computer Science Education, ACM Transactions on Computing Education, SIGCSE, FIE). The work aimed to include both recent research (papers published from 2010 onwards) and some older, foundational works that laid the groundwork for understanding certain phenomena (e.g., early works on pair programming). Together, the selected papers provide a broader picture, presenting different perspectives and/or methodological approaches to the same problem.

Threats to Validity and Scope

This review is limited by the breadth of the topic and the heterogeneity of the underlying evidence. Because the search prioritized relevance to higher education and professional software engineering, it may underrepresent earlier pipeline factors and contexts where peer-reviewed studies are sparse. In addition, differences in how primary studies operationalize constructs such as “belonging,” “retention,” or “work culture” make direct comparisons difficult. Consequently, the results should be interpreted as a structured synthesis of themes rather than a meta-analysis. Where findings across papers diverged, the review reports the range of perspectives and highlights open questions that require more systematic and longitudinal evidence.

Results

This section presents the relevant papers from the literature review, structured according to the research questions.

RQ1

Table 1 provides a summary of the key obstacles, grouped by thematic areas that proved dominant in the research.

Table 1. Overview of key obstacles faced by female students and/or employees in the educational domain - RQ1(a)

Obstacle	Relevant Works
Gender stereotypes ("male field")	(Ferati & Vogel, 2020; Beyer, 2014; Naz et al., 2020; Petrovska et al., 2020)
Lack of self-confidence	(Beyer, 2014)
Lack of female role models	(Ross et al., 2020; Grande et al., 2018)
Feeling of not belonging and isolation	(Grande et al., 2018; Morgan, 2017; Barker et al., 2009)
Differences in prior programming experience	(Morgan, 2017)
Gender bias present in educational software tools	(O'Brien et al., 2025)
Additional barriers for women from minority groups	(Ross et al., 2020)
Different motivational factors	(Naz et al., 2020; Lehman et al., 2016; Ryan & Deci, 2000)

While Tables 1 and 2 separate education and workplace contexts, the literature suggests that these domains are tightly coupled. Early experiences that reduce self-efficacy or belonging, such as stereotype-driven classroom climates and the absence of visible role models, can influence later career intentions and the confidence to pursue internships, networking opportunities, and leadership roles. Conversely, workplace cultures that normalize bias or penalize caregiving responsibilities can retrospectively validate students' concerns that they "do not fit" in the field, reinforcing a cycle of underrepresentation.

Across the reviewed studies, three cross-cutting patterns emerge: (1) many obstacles are cumulative rather than isolated (e.g., limited prior experience can interact with a hostile peer culture to amplify isolation); (2) social mechanisms-peer recognition, feedback quality, and access to informal networks - often determine whether technical ability is translated into persistence; and (3) online and hybrid contexts can both help (through access to wider communities) and harm (through visibility gaps and unmoderated bias), depending on how platforms and courses are designed.

Table 2. Overview of key obstacles faced by women as employees in the work domain related to software engineering - RQ1(b)

Obstacle	Relevant Works
Gender bias in hiring and promotion	(Fine et al., 2020)
Lack of flexibility (working hours, remote work)	(Chu & Kennedy, 2011; Löfström & Nevgi, 2007)
Unsupportive work culture	(Williams, 2014)
Work-life balance challenges	(Chu & Kennedy, 2011; Löfström & Nevgi, 2007)

RQ2

Tables 3 and 4 similarly indicate that effective supports rarely operate as single interventions. In education, approaches that combine structured collaboration (e.g., pair programming) with inclusive teaching practices and visible communities can simultaneously address skills development and psychosocial needs such as belonging. In the workplace, flexible arrangements are most effective when paired with organizational norms that prevent flexibility from being interpreted as reduced commitment, and when mentorship and sponsorship are backed by transparent advancement criteria.

Taken together, the evidence points toward ecosystem-level solutions: interventions that treat participation and success as outcomes of the interaction between individuals, learning/work practices, and institutional culture. The following discussion therefore interprets the findings with an emphasis on how barriers and supports connect across stages, and how they can be operationalized in both in-person and remote settings.

Table 3. Factors that can have a positive and supportive impact on the successful participation and achievement of women in the field of education – RQ2(a)

Supporting Factor	Relevant Works
Pair programming	(Werner & Denner, 2009; Werner et al., 2004; Graßl & Fraser, 2024)
Creating an inclusive environment through collaboration and belonging	(Washington, 2020; Morgan, 2017)
Active role of instructors	(Washington, 2020; Goode, 2007)
Targeted interventions (customized courses, mentoring)	(Alvarado & Dodds, 2010)
Peer-led team learning	(Horwitz & Rodger, 2009)
Visibility and interaction with peers (especially online)	(Morgan, 2017)
Use of gender-inclusive educational software tools	(O'Brien et al., 2025)

Table 4. Factors that have a positive and supportive impact on the successful participation and achievement of women in the field of practical work related to software engineering – RQ2(b)

Supporting Factor	Relevant Works
Flexible work arrangements	(Chu & Kennedy, 2011; Löfström & Nevgi, 2007)
Mentorship and sponsorship programs	(Grande et al., 2018)
Gender equality and inclusion initiatives	(Fine et al., 2020; Washington, 2020)
Supportive work culture	(Fine et al., 2020; Williams, 2014)
Continuous work on the inclusion of women	(Arnold, 2016; Arizona State University n.d.)

Discussion

This chapter provides a detailed analysis and interpretation of the results presented in the results section. The discussion connects the identified obstacles and supporting factors and places them in a broader context to provide comprehensive answers to the research questions.

Response to RQ1

(a) Educational Domain

The analysis of the literature indicates a complex interaction of socio-cultural, psychological, and structural obstacles that female students encounter during their education in software engineering. Deeply rooted gender stereotypes that portray software engineering as a predominantly "male" field (Ferati & Vogel, 2020) represent a significant initial barrier (Naz et al., 2020; Petrovska et al., 2020). Their impact is not only in deterring girls from choosing this field of study but, as Beyer (2014) emphasizes, they directly undermine the self-efficacy, interests, and values of those women who do opt for this field. This psychological burden, manifested as a lack of self-confidence, can prevent them from taking risks and engaging in challenging tasks, which are crucial for developing programming skills.

This individual psychological effect is further amplified by the structural lack of visible female role models in academia and industry (Ross et al., 2020; Grande et al., 2018). The absence of readily available examples of successful women makes it difficult for female students to identify with and envision their own successful future in the profession, which consequently leads to a feeling of not belonging. This sense of isolation is not abstract; it manifests in daily interactions and is potentially exacerbated by differences in prior programming experience that can hinder integration into predominantly male study groups (Barker et al., 2009).

It is important to note that these problems spill over into online learning and collaboration spaces. Morgan's (2017) research on the Stack Overflow platform shows how the stark underrepresentation of women and the rarity of interaction among them can discourage their further participation, likely due to fear of negative reactions or feelings of incompetence. This suggests that online environments, despite potential anonymity, can cause or even amplify the sense of isolation and barriers present in the physical world.

Furthermore, the problem becomes more complex through intersectionality, where women from minority groups face additional, specific forms of marginalization (Ross et al., 2020). Even motivational factors can differ (Naz

et al., 2020), indicating the unique needs and obstacles that women face (Lehman et al., 2016; Ryan & Deci, 2000). Finally, the potential bias of educational software tools themselves should not be overlooked, as they may "favor" certain learning or interaction styles, as suggested by the work of O'Brien et al. (2025), further complicating the path for female students.

(b) Work Domain

The obstacles identified in education often continue or take new forms in the professional environment. Gender bias, often unconscious, can permeate hiring and promotion processes (Fine et al., 2020), limiting women's career opportunities despite their qualifications. Structural inflexibility, such as rigid working hours or limited remote work options (Chu & Kennedy, 2011; Löfström & Nevgi, 2007), represents a significant barrier, especially for women who traditionally bear a greater share of family responsibilities, leading to challenges in achieving a work-life balance. Beyond these specific practices, an unsupportive work culture plays a key role. Phenomena such as subtle or overt sexism, microaggressions, and the lack of adequate mentorship or sponsorship can create an undesirable environment where women do not feel valued or supported (Williams, 2014).

Response to RQ2

(a) Educational Domain

In contrast to the identified obstacles, the literature offers a range of strategies that act as important supporting factors. It is crucial to note how many of these strategies directly address specific obstacles. For example, pair programming (Werner & Denner, 2009; Graßl & Fraser, 2024) not only improves technical skills but, through collaboration, directly alleviates feelings of isolation and builds self-confidence (Graßl & Fraser, 2024), which are key psychological barriers. Similarly, strategies like peer-led team learning (Horwitz & Rodger, 2009) strengthen the support network and sense of belonging. A broader approach involves consciously creating an inclusive learning environment that promotes collaboration and respect for diversity (Barker et al., 2009; Washington, 2020). This is not just a matter of atmosphere but also requires competent instructors (Washington, 2020) who actively encourage the interest and self-confidence of female students (Goode, 2007) and are educated about unconscious biases. Targeted interventions, such as specially designed courses, mentoring programs, or student clubs for women (Alvarado & Dodds, 2010), have proven effective in providing specific support and building community.

It is important to recognize that technology can also be a supporting factor if used in an inclusive way. The work of O'Brien et al. (2025) primarily identifies potential biases but also points to the importance of selecting and designing gender-inclusive educational tools that consider the different needs and preferences of students. In the context of e-learning, these supporting factors can be implemented through online discussion forums, virtual study groups, online mentoring programs, and the inclusive design of online courses that considers different learning styles and provides clear instructions and expectations. Visibility and interaction with female peers, even in an online space, can have an encouraging effect (Morgan, 2017).

(b) Work Domain

Supporting factors in the work environment reflect the need for systemic changes within organizations. Flexible work arrangements (Chu & Kennedy, 2011; Löfström & Nevgi, 2007) are not just a perk but a key element that allows for a better balance between professional and private obligations, directly targeting one of the main structural obstacles. Formalized mentorship and sponsorship programs (Grande et al., 2018) provide much-needed support in navigating the corporate structure and open doors for advancement, counteracting the effects of a lack of informal networks and potential bias. However, individual measures are insufficient without broader initiatives for gender equality and inclusion and the cultivation of a truly supportive work culture. This involves actively combating sexism (Williams, 2014), transparent promotion processes, and valuing the contributions of all employees (Fine et al., 2020).

In a virtual work environment, these principles require conscious adaptation through online collaboration tools, virtual mentoring, and clear communication channels that promote inclusivity. Prominent examples, such as the long-standing work and advocacy of Mary Anderson-Rowland (Arnold, 2016; Arizona State University n.d.),

demonstrate the indispensable role of continuous, dedicated work by individuals and institutions in creating long-term change and supporting new generations of women in software engineering.

Practical Implications and Recommendations

Recommendations for Higher Education

A recurring implication across studies is that technical instruction and inclusion cannot be treated as separate concerns. Course design can reduce isolation by making collaboration an explicit learning goal (e.g., structured pair or small-group programming with rotating roles) and by assessing both process and outcomes, which helps normalize help-seeking and shared problem solving.

Instructors can further support persistence by setting clear expectations for respectful teamwork, intervening when peer dynamics marginalize students, and using examples and assignments that connect software engineering to socially meaningful applications. This aligns with evidence that motivation and values can differ across groups, and that relevance can influence sustained engagement.

Finally, visibility matters. Even in large programs, relatively low-cost practices, such as inviting guest speakers, highlighting diverse alumni pathways, and creating mentoring touchpoints early in the curriculum-can help students form realistic professional identities and counter the “male field” stereotype.

Recommendations for Employers and Teams

In professional settings, the reviewed literature suggests that addressing bias requires both policy and everyday practice. Organizations can reduce subjective decision-making by clarifying role expectations, standardizing evaluation criteria, and documenting promotion decisions, which helps mitigate the impact of informal networks and assumptions about “fit.”

Flexible work options are most supportive when accompanied by norms that protect access to high-visibility projects and career development. For example, managers can proactively monitor task allocation, ensure that remote employees are not excluded from key discussions, and treat flexibility as a normal part of team operations rather than an exception.

Mentorship and sponsorship programs benefit from explicit goals: mentorship that supports skill building and navigation of workplace culture, and sponsorship that actively advocates for opportunities. Combined with a supportive culture that addresses microaggressions and discourages harassment, these practices can improve retention and advancement for women across career stages.

Open Questions

One of the key methodological shortcomings of existing research is the relative rarity of longitudinal studies. Most papers provide a snapshot in time, but there is a lack of tracking the trajectories of women through the education system and their careers in software engineering over a longer period. Such studies are necessary for a better understanding of the critical points at which women drop out, the long-term effects of early experiences-such as the impact of stereotypes as described by Beyer (2014) and the true effectiveness of various interventions (Alvarado & Dodds, 2010) on the retention and advancement of women in the profession.

Although quantitative research provides valuable data on trends and correlations, there is a need for more qualitative research. In-depth interviews, case studies, and ethnographic observations can provide richer insight into the subjective experiences, perceptions, and coping strategies of women, and give deeper meaning to quantitative results about the sense of (not) belonging (Grande et al., 2018) or the impact of work culture (Williams, 2014).

The context of e-learning and remote work deserves special attention in future research. Given the growing importance of online models, it is crucial to investigate how obstacles and supporting factors manifest in a virtual environment. Experiences from online communities like Stack Overflow (Morgan, 2017) or questions of tool bias (O’Brien et al., 2025) suggest specific challenges and dynamics. It is necessary to systematically

investigate the effectiveness of online implementations of strategies such as pair programming (Werner et al., 2004), mentoring, or building a support community (Graßl & Fraser, 2024). It is necessary to develop and evaluate inclusive pedagogical practices specific to online courses and to analyze in more detail the impact of gender stereotypes in virtual teamwork.

A significant gap also exists in the understanding of intersectionality. While some studies have begun to explore the experiences of women from minority groups (Ross et al., 2020), more systematic research is needed to investigate how gender intersects with other identity categories and how these intersections shape the specific challenges and needs of women at different stages of their education and career in software engineering. Furthermore, it is worth investigating how to better bridge the gap between interventions at the level of a single course or project and the need for systemic, institutional changes, keeping in mind the importance of creating an inclusive environment at the level of the entire institution (Washington, 2020).

Another promising direction is to evaluate interventions using comparable outcome measures across contexts. Future studies could more consistently report retention, sense of belonging, self-efficacy, and participation metrics, enabling more reliable comparisons between pedagogical approaches and organizational programs. Research is also needed on the design and governance of sociotechnical platforms that mediate learning and work. Platform affordances - such as reputation systems, moderation policies, and feedback visibility may influence whose contributions are recognized and whose questions are answered, which is particularly relevant for online learning communities and distributed software teams.

Finally, more work is needed to understand how supportive factors scale. Many successful interventions are piloted in a single course or organization; longitudinal multi-site evaluations would clarify which elements are essential, which are context-dependent, and how institutions can sustain changes once initial champions or funding sources are no longer present.

Conclusion

This review highlights that women in computer science continue to face persistent and interconnected barriers across both educational and professional contexts. The findings indicate that these barriers are not limited to individual-level factors, but are also shaped by stereotypes, biased evaluation practices, reduced sense of belonging, and structural conditions in learning and work environments (Lehman et al., 2016; Fine et al., 2020; Washington, 2020; O'Brien et al., 2025). At the same time, the reviewed studies show that supportive teaching practices, inclusive peer collaboration, mentoring, and visible role models can positively influence confidence, participation, and persistence in computing pathways (Werner et al., 2004; Werner & Denner, 2009; Graßl & Fraser, 2024).

A key implication of this review is that improving women's participation in computer science requires a multi-level approach: interventions should address classroom climate and pedagogy, transition points into employment, and organizational practices that shape inclusion and advancement (Beyer, 2014; Fine et al., 2020; Ross et al., 2020). Rather than treating underrepresentation as a matter of individual preference or motivation alone, future research and practice should focus on how educational and professional systems can be designed to reduce bias and strengthen equitable participation over time (Lehman et al., 2016; Washington, 2020). Overall, the findings suggest that sustained progress depends on combining institutional support, inclusive practices, and continued evaluation of interventions in both academic and workplace settings (Grande et al., 2018; Graßl & Fraser, 2024; O'Brien et al., 2025).

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article belongs to the authors.

* This study is a literature review and did not involve human participants or primary data collection requiring ethics committee approval.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

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