Female-inclusive Practices for Software Engineering and Computer Science Higher Education: A Literature Review

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Abstract

There have been discussions about the gender gap in STEM majors. While some fields (e.g., Biomedical Sciences) have a high proportion of women workers, the Computer Science (CS) and Software Engineering (SE) disciplines are lacking female specialists. Universities worldwide are implementing different practices to attract more women to the CS and SE programs. This literature review aims to collect literature on this topic, identify the research tendencies, and collect female-inclusive practices. This paper presents the main findings from analyzing 143 selected papers from five academic databases (IEEE, ACM, Web of Science, Science Direct, and Scopus). The analysis revealed the need for inclusivity across all education stages, emphasizing practical studies beyond the classroom. Twenty-eight gender-inclusive practices were identified.

Keywords

software engineering, computer science, ICT, gender, diversity, education, literature review

1. Introduction

The low ratio of women in STEM interests researchers around the world [10]. Special attention is paid to the fields that face higher gender imbalance: Mechanical and Electrical Engineering, Physics, Math, and Computer Science [26, 33]. Gender balance in tech may bring many benefits to the field. Firstly, there is a growing demand for ICT and high-tech technology specialists, and bringing more women to the field may fill the workforce gap [42]. Secondly, diversity brings innovative ideas and stimulates knowledge-sharing and innovative thinking [89]. And thirdly, diverse teams have a better understanding of different users' needs [25].

The understanding of the gender challenges in SE and CS education, different students' needs, and practices that help to eliminate the gender gap may help universities and other tertiary educational institutions to achieve a better balance in the programs.

This study aims to summarize current knowledge regarding gender-inclusive practices in Software Engineering (SE) and Computer Science (CS) higher education and guide implementation and further research. This study sought to answer the following research questions:

RQ1: What is the state-of-the-art gender research in SE and CS tertiary education?

This question aims to provide an overview of the current state of gender research, specifically within Software Engineering and Computer Science higher education. It sets the foundation for understanding this area's existing literature and knowledge base.

RQ2: Which gender-inclusive practices are provided in the literature?

This question focuses on identifying existing gender-inclusive practices documented in the literature. It seeks to compile a comprehensive list of strategies and approaches that have been proposed or implemented to promote inclusivity in SE and CS education.

RQ3: To what extent have these practices been researched, and are they ready for implementation?

This question delves deeper into the effectiveness and readiness of the identified gender-inclusive practices. It seeks to assess the level of research and

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evidence supporting each practice and determine their feasibility for implementation in SE and CS higher education settings.

2. Background

Historically, labor division was explained by different physical strength requirements and cultural beliefs regarding gender roles. Nowadays, technologies have replaced humans in many physical tasks and allowed women to enter previously male-dominated professions. However, the gender gap persists in many fields, including Computer Science (CS), Software Engineering (SE), physics, mathematics, etc.

Social factors like the pressure of stereotypes, dominant social norms, and habits currently explain the low female presence in tech [22]. For example, one sociocultural habit is encouraging boys to develop their computer skills, while girls rarely play computer games or participate in advanced computer classes [55]. At school ages, educators and parents may influence their career decisions based on social norms [40, 85]. Young women who faced gender discrimination during their childhood and adolescence most likely will feel less confident about entering the male-dominant field [22, 33]. Even women already studying CS as their major rate their computer, mathematics, and intellectual skills lower than male students [54]. Therefore, even if girls decide to enter engineering fields by choosing an educational program in technology and later a technology-related career, there is still a considerable risk that they keep feeling discomfort and drop out of school or switch to another career path [14, 51] as women are 2.5 times more likely to leave a computing career than men [55].

However, the feeling of belonging and self-efficacy beliefs may be fixed by gender-inclusive interventions [9, 61]. For example, the study by Lewis et al. found that some students could easily reject the stereotypes about computer science when they could provide an example of cases when the reality did not match these stereotypes [51]. Thus, even by sharing and promoting non-stereotypical stories, society can move forward to the gender balance in CS. Indeed, there are more complex measures that could be implemented in different institutions to close the gender gap. At the university level, these activities could be introduced in enrollment, learning processes, social activities, and more [43]. The explanations of the current situation and possible solutions for better gender balance are already presented in the literature. This study will help to systematize the body of knowledge about gender research in SE and CS tertiary education and summarize the gender-inclusive practices that researchers suggest.

3. Method

To build an understanding of existing knowledge, we used the Scoping Literature Review that, by its nature, attempts to build a comprehensive understanding of the existing research activities [68]. The search was performed systematically, and the sample is based on the search results from five academic publication databases (Scopus, IEEE, ACM, Web of Science, Science Direct) aiming to summarize current knowledge regarding gender-inclusive practices in Software Engineering (SE) and Computer Science (CS) higher education.

The review process started with literature selection, which consisted of the following stages: keyword generation and tests, literature collection, and inclusion [72].

Firstly, keywords were generated. Logically, they were divided into three groups: “gender keywords,” “educational level,” and “SE and CS.” After several search tests and modifications, we ended up with the following list of keywords, presented in Figure 1.

Considering the fast growth of SE and CS industries, the search for publications was limited, starting from 2015 to 2022. The search was also limited to the literature in English. After the exclusion of duplicates, the total number of found literature samples from the selected five databases was 882 unique studies. Then, the selection and exclusion processes were initiated. This process consisted of the following steps: inclusion criteria identification, title-based evaluation, abstracts-based evaluation, and finally, full text-based evaluation.

For the inclusion, we have identified the following criteria:

- The study should be focused on a female experience or gender differences.
- The study must be related to higher education.
- The study must focus on CS, SE, or ICT.

During the evaluation, 143 publications were selected for the final list. The full process is presented in Figure 1.

Then, following the study goal, we performed a literature analysis to understand the current state of research, summarize gender-inclusive practices, and define the focus of future research. The following sections contain the main findings of this literature analysis.

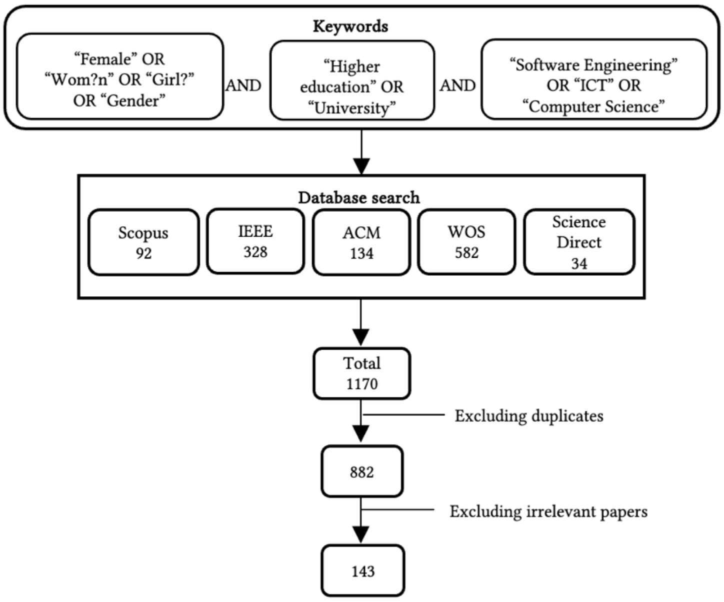

Figure 1: Keywords and search process.

4. Results

The included academic publications literature set consisted of 105 conference papers, 36 journal articles, and 2 book chapters.

4.1. Literature overview

During analysis, the literature was grouped based on the following dimensions: research results, focus area, and students' experience. The literature distribution map is presented in Figure 2.

The "research results" dimension presents the main output of every research paper; it consists of "observations and explanations," "proposals," and "practical implementations." Literature from the "observations and explanations" provides an understanding of the experiences of female students from SE and CS and their main characteristics. "Proposals" suggest what could be done to improve the gender situation. And "practical implementations" provide the results of implementing gender-inclusive initiatives. The total number of studies in each group is 59, 35, and 49, respectively.

Considering the "focus areas," papers could be grouped into those focusing on courses or initiatives, university-level activities, or broader perspectives. At a course level, researchers observed the student's behavior in class and suggested techniques to improve the female experience in the course. For example, Ying and colleagues [88] investigated the effect of pair programming on male and female students. At the same time, Al-Tahat et al. [3] assessed the impact of 3D visual practical implementations on female students' performance in computer programming. The university-level group considers observations, activities, and strategies that go beyond the classroom. Thus, Narayanan et al. [63] describe the recruitment process, which emphasizes the opportunities for computing jobs and their real-world impact, providing tutoring, building a learning community among students, and having internships during the program. Janzen et al. [35] , in addition to special approaches to the courses, suggest supporting informal activities, clubs, and celebrations of women in computing. From a broader perspective, we consider the papers that suggest a more complex approach, requiring additional observations or initiatives outside the university activities. Thus, for instance, Main and Schimpf [55] , in their study, investigate different life stages of women in CS. Wang et al. observe social factors that define female intentions to study CS [85]. The analysis showed that the majority (81) of papers focus on the University level in general, 46 study courses or initiatives, and only 16 overviews a broader perspective.

The authors investigate female students' experiences in the field: enrollment, learning process, interest and motivation, and persistence.

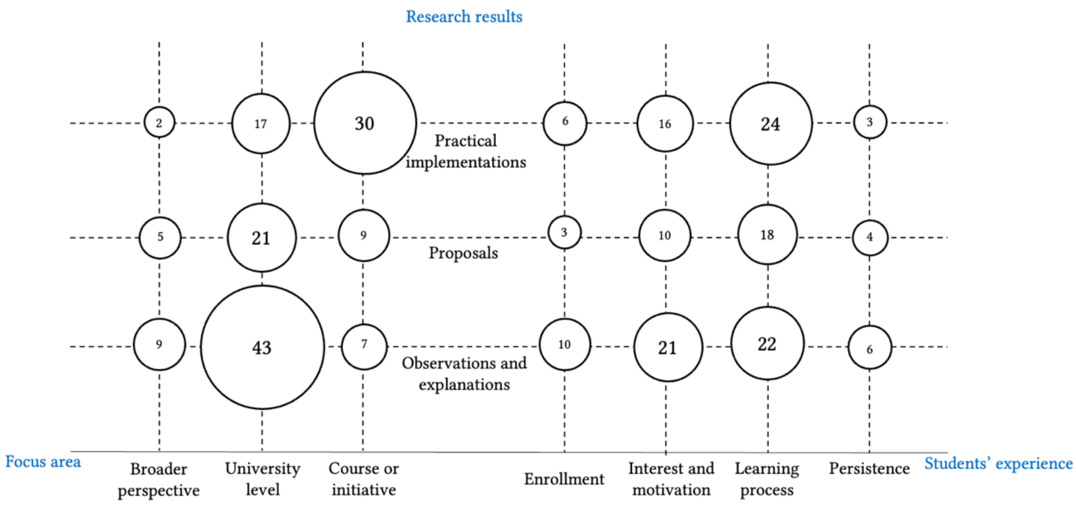

Figure 2: Literature map.

Most (64) publications consider the learning process the main focus of the study. A little less common (47) are studies that study female interest and motivation in general, then enrollment (19) and persistence (13).

The following observations addressing the RQ1 can be seen from this map:

1. The smaller the focus area is, the more practical tests researchers make. Testing the measures and assessing their effectiveness in a classroom context is easier than in the university or society. Meanwhile, observing female behavior and feelings from the course perspective could expand the understanding of potential improvements that are needed in the learning process.
2. From the students' experience perspective, only 13 of the studies consider female persistence in the field. If society aims to have a gender balance in CS and SE education and the industry in general, there is a need to ensure the inclusivity of all stages of the educational process not only to attract more women but also to lead them to graduation and employment.
3. There is low interest in female enrollment. Indeed, improving the learning environment and female education experience in SE and CS education is important. However, it is impossible to achieve a gender-balanced program without increasing the number of women entering the university to study SE and CS.
4. Overall, there is a quite high number of practical studies investigating the phenomena. However, most of them present initiatives implemented in the learning process. Therefore, more practical studies regarding enrollment, interest and motivation, and persistence are needed.

4.2. Literature analysis

To answer the RQ2 and RQ3, further analysis was focused on the "Research Results" dimension. To understand which gender-inclusive activities researchers suggest, "Practical implementation" and "Proposals" were analyzed.

Practical implementations present the results of actions that were tested and implemented in practice. Proposals suggest ways to improve the CS and SE programs. They are based on literature, interviews, early-stage practical tests, and other promising results that suggest the need for more practical tests.

Overall, the practices were combined into 28 categories, as presented in Table 1. Not all the activities are specifically focused on gender. However, they proved to have a positive impact on female audiences. Therefore, the practices were divided into gender-specific and gender-neutral [43] recommendations.

Table 1
Gender-inclusive practices.

Gender-inclusive practice	Practical implementations	Proposals	Description
		Gender-specific recommendations	
Outreach activities	[10, 12, 16, 24, 28, 39, 48, 50, 60, 63, 65, 70, 71, 73, 79, 80]	[2, 6, 11, 32, 37, 74, 77]	Promotion of computing through engagement: school visits, workshops, hackathons, summer camps, etc.
Building female community	[35, 45, 63, 64, 76, 86, 87]	[2, 5, 7, 32, 36, 37, 47, 58, 78, 84]	Arranging networking opportunities for female students outside of classes
Female-focused marketing	[28, 75]	[2, 58, 59]	Including female-inclusivity in marketing activities and materials
Gender talks	[24, 75]	[27, 32, 34, 58, 84]	Acknowledging gender issues in and outside of the class and presenting successful female speakers
Diverse teaching staff	[75]	[4, 34, 36, 47]	Ensuring faculty diversity
Female-only environment	[50, 87]		Making female-only courses, events, and programs
Targeted recruitment	[38]	[6, 36]	Having quotas for women
Gender-inclusive materials	[1, 62]	[37, 52, 69]	Ensuring that educational materials are free from stereotypes and biases
Inclusive environment	[56, 76]	[4, 8, 13, 36, 58, 81, 84]	Ensuring that the university has diversity-supporting policies, zero tolerance for discrimination; covering female needs, etc.
Creation of a diversity-focused action group		[7]	Creating separate department responsible for diversity
Faculty training		[7, 8, 18, 19, 34, 36, 53, 59, 69]	Educating teaching staff about gender-inclusive tactics and principles in education
		Gender-neutral recommendations	
Industry collaboration	[15, 86]	[27, 37, 47, 59, 77]	Involving industry in education
Gamification	[3, 38, 44, 66, 67]	[27, 29]	Using gamification in educational processes
Mentoring	[10, 23, 38, 44, 45, 63, 64, 76, 79, 86]	[4, 7, 8, 19, 27, 32, 36, 37, 52, 53, 58, 77, 78, 84]	Support students with mentors and tutors
Preliminary training	[10, 63, 75]	[53, 74]	Filling the educational gaps before the program/course starts
Growth mindset interventions	[15]	[41, 84]	Encouraging students to focus on learning and expanding their knowledge
Practical focus	[12, 30, 31, 35, 38, 41, 45, 63, 75]	[2, 47]	Focusing education on practical implementations of knowledge
Teamwork/peer-learning	[30, 35, 38, 44–46, 49, 50, 75, 88]	[6, 37, 52, 78, 81, 84]	Encouraging collaboration and working in a team
Physical computing	[12, 39, 80, 83]		Using hardware, robots, etc. in studies
Flipped classroom	[49, 79]	[37]	Combining in-class and self-learning
Focus on impact	[1, 38, 57, 63, 67, 70]	[5, 20, 82, 84]	Demonstrating social effect of computing
Collaboration with parents and high-school teachers	[28, 64, 70]	[6, 8]	Educating parents and high school teachers about computing
Real-life focus	[12, 17, 30, 35, 38, 41, 44, 67]	[36, 84]	Providing relatable examples and tasks
Use of social media	[41]		Using social media in education
Storytelling	[67]		Creating learning based on narrative
Interdisciplinarity	[65]	[37, 59, 84]	Making cross-disciplinary tasks, courses, and programs
Professional orientation		[2, 5, 6, 37, 47, 77, 84]	Educating students about their career prospects; supporting their employment
Project/problem-based learning	[31, 35, 45, 50]	[27, 37, 81, 84]	Engaging students in problem and project-based tasks

Based on the frequency of appearance in the literature, the recommendations for researchers and practitioners were made and presented in Table 2.

Table 2
Recommendations for researchers and practitioners

Practically tested
• Outreach activities
• Mentoring
• Teamwork/peer-learning
• Practical focus
• Real-life focus
• Building female community
• Focus on impact
• Gamification
• Project/problem-based learning
• Physical computing
Needed to be introduced in practice
• Inclusive environment
• Gender talks
• Industry collaboration
• Diverse teaching staff
• Faculty training
• Professional orientation
Research needed
• Preliminary training
• Collaboration with parents and high-school teachers
• Female-focused marketing
• Gender-inclusive materials
• Flipped classroom
• Female-only environment
• Interdisciplinarity
• Growth mindset interventions
• Targeted recruiting
• Use of social media
• Storytelling
• Creation of a diversity-focused action group

Some practices were widely researched and tested and proved to be effective in engaging female audiences. Therefore, they can be actively introduced in university activities to boost diversity. Practices that were mentioned in practical implementations more frequently (four times or more) are considered “practically tested” and suggested to be implemented for improving diversity.

On the other hand, some practices are frequently proposed (four times or more) as effective ways to engage female students in computing. These practices were grouped into “needed to be introduced in practice.” The last group combines the most under-researched practices and requires additional studies.

5. Discussion and conclusion

The underrepresentation of women in STEM fields, particularly in Mechanical and Electrical Engineering, Physics, Math, and Computer Science, remains a significant concern globally. Achieving gender balance in technology fields holds immense potential benefits, including addressing workforce shortages, fostering innovation through diverse perspectives, and enhancing user-centric design.

This study addresses the gender gap in Software Engineering (SE) and Computer Science (CS) higher education by summarizing current knowledge on gender-inclusive practices and providing guidance for implementation and further research.

The methodology employed a Scoping Literature Review to comprehensively understand existing research activities regarding gender-inclusive practices in Software Engineering (SE) and Computer Science (CS) higher education. The review process began with systematic searches across five academic publication databases, namely ACM, IEEE, Scopus, Web of Science, and Science Direct, resulting in a final selection of 143 unique contributing studies.

The analysis of the literature involved grouping based on research results, focus areas, and stages of the educational process. Within the "research results" dimension, literature was categorized into "observations and explanations," "proposals," and "practical implementations," providing insights into female experiences in SE and CS, suggestions for improvement, and outcomes of gender-inclusive initiatives. More practical tests were made on a course or initiative level as it is easier to evaluate initiatives and their effectiveness in a classroom setting compared to a university or society-wide context. Meanwhile, observations from the course level are quite limited. Considering female students’ experience, the emphasis was largely on the learning process; fewer studies addressed enrollment, motivation, and persistence. Observations from this analysis highlight the need for inclusivity across all stages of education to achieve gender balance in SE and CS, emphasizing the importance of practical studies beyond the classroom setting, particularly in enrollment and persistence initiatives.

With a deeper literature analysis, 28 gender-inclusive practices were identified. Some of the practices are less researched than others, so they were grouped according to their frequency of appearance in the literature.

Tertiary education institutions are suggested to implement outreach activities, mentoring, teamwork/peer-learning, practical focus, real-life focus, building female community, focus on impact, gamification, project/problem-based learning, and physical computing for improving gender diversity.

Studies encourage the introduction of an inclusive environment, gender talks, industry collaboration, diverse teaching staff, faculty training, and professional orientation.

More research is needed for preliminary training, collaboration with parents and high-school teachers, female-focused marketing, gender-inclusive materials, flipped classrooms, female-only environments, interdisciplinarity, growth mindset interventions, targeted recruiting, social media use, storytelling, and the creation of a diversity-focused action group.

The authors acknowledge certain limitations of this study. Firstly, focusing exclusively on computer science and software engineering may not capture the complete spectrum of gender inclusivity challenges present across all STEM fields. This narrow focus might overlook valuable insights and practices from other STEM disciplines that could contribute to a more comprehensive understanding of gender inclusivity in education and the workforce. Limiting the study to higher education institutions may exclude potential insights from industry or non-traditional educational settings. Thus, while the paper provides valuable insights within its defined parameters, it is essential to recognize these limitations and encourage further research to explore gender inclusivity across diverse STEM fields and educational contexts.

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