Problems faced by female computer science undergraduates: a systematic review*[1]

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Abstract

This systematic literature review on the issues faced by female computer science undergraduates sought to examine the reported reasons for female evasion from computer science major. A full range of indexed journals was surveyed using the ACM Digital Library, IEEE Xplore, ScienceDirect, Scopus, Web of Science, and Springer databases. Of the 818 articles retrieved from the digital libraries, only 24 papers were selected for data extraction. The several issues cited as reasons for female evasion from computer science undergraduate courses were divided into six major categories and described. Initiatives that have been implemented to minimize the dropout rate among undergraduate computer science female students were also addressed. Pointing out the main issues faced by female computer science students and identifying the limitations of the initiatives taken to solve them is the first step for future work, proposing good ways around them and outlining specific solutions for the classroom, making education professionals and even classmates aware of these problem. Attention to these issues may pique the researchers' interest, while pursuing a graduate STEM degree, in working to make the experience of female undergraduate students more positive, thus decreasing their chances of evasion. Moreover, based on the results of this research, it is possible to make theory-based academic, managerial and administrative decisions concerning gender issues.

Keywords

Computer science – Gender discrimination – Evasion – Undergraduate students – Systematic review.

* The authors take full responsibility for the translation of the text, including titles of books/articles and the quotations originally published in Portuguese.

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Introduction

The impressive dropout rate from computer science courses among women is hardly a secret. Given the centrality of technology in the contemporary economy and society, educators, policymakers, sociologists, and other professionals have been concerned about unequal gender participation in engineering and science careers. Gender issues are particularly significant in computing science education, with some important ones concerning the reasons for why so few women choose to study computer science, and which factors lead them to dropping out and declining a computer career (MISA, 2011).

The literature points out many issues faced by women in computer science. Gender stereotype, humiliation, objectification, and prejudice are daily challenges for women who struggle for a space in technology, starting even before entering university and usually extending throughout their careers. Gender bias begins early, before college, when family members do not support the choice of a technological course; when teachers and classmates underestimate the technical capacity of female students and diminish their merits. Combining these facts to a lack of female references working in computer science, girls are discouraged to enter and stay in the area (BERG; SHARPE; AITKIN, 2018; GOMES *et al*., 2018).

According to Strayhorn (2018), the sense of belonging differs according to students' social identities, such as race, gender, and sexual orientation, and the conditions they encounter on campus. Both social segregation and academic unpreparedness are evident among women from working and middle class families. In contrast, women from upper-class families show a continuation of family traditions. Class plays a significant role in construing marks that define "belonging" at elite universities (OSTROVE, 2003).

Some studies suggest that one main reason why women dropout of computer science university courses is the feeling of not belong in the field or major (BARKER; COHOON; THOMPSON, 2010; COHOON, 2002; MARGOLIS, 2002). Since a sense of belonging is a well-known predictor of success in college, especially within STEM, discussions on diversity have identified it as a critical component of diversity and inclusion efforts in the tech industry (STRAYHORN, 2018). According to the literature, undergraduate students who experience a greater sense of belonging feel more connected to their environment and are more likely to persist to graduation. Female students experience computing environments differently due to sexism, which potentially leads them to feel unwelcome and lacking a sense of belonging to computing spaces (SAX *et al*., 2018).

Barker, Hovey, and Thompson (2014) emphasize the importance of classroom experiences for student permanence. Regarding the sense of belonging, they argue that classrooms are the main venue where students are exposed. Knowledge, presentation, and expectations about the types of people who do (or do not) belong in a undergraduate program, while being a minority in the classroom and facing various gender stereotypes, results in a loss of confidence for women, which can then lead to switching majors (BARKER; HOVEY; THOMPSON, 2014).

The gender gap is an issue that concerns both educators and professionals in the field. Computing is an area that presents a high overall dropout rate, and the absence of women contributes to the steep decline in university enrollment (MISA, 2011). Computer science programs are looking for ways to improve permanence and satisfaction for all

students, partly due to low enrollment and high dropout rates. Diversity in the field is also important, as it increases creativity and provides a better understanding of customer's needs (CARLSON, 2006).

A major tool used to aggregate the experiences gained from a range of different studies to answer specific research questions is the systematic literature review (KITCHENHAM; CHARTERS, 2007). Despite challenges faced by women in computer science majors and their consequences, such as lacking a sense of belonging, no systematic reviews were found between 2015 and 2020 that addressed this topic. We opted for limiting our search to this period because gender issues in computer science are relatively recent and the decline in the number of women enrolled in the field is increasing (MISA, 2011). Given the plethora of issues faced by women in computer science, which will be reported in the next section, a study that establishes a shared sense in the literature is of paramount importance. More specifically, this systematic review identifies, delimits, and categorizes the problems experienced by female undergraduate computer science students to verify how such issues relate to the lack of a sense of belonging and, additionally, what is being done to solve them.

Negative experiences in computer science

Computer scientists are stereotyped as socially inept, brilliant, and obsessively focused on technology (CHERYAN; MASTER; MELTZOFF, 2015). A study carried out in two secondary schools in Scotland in 2018 revealed patterns of stereotypes and social expectations children have regarding women who pursue careers in computer science. Data was collected by means of rich picture (collaborative drawing), a mechanism for exploring multiple opinions. Before the activity began, children were asked to express, via drawings, why there were few women in computing and what women who followed this career were like. The findings indicated quite negative physical and behavioral stereotypes (BERG; SHARPE; AITKIN, 2018).

Gender-based discrimination against women is more noticeable in the job market, given the wage gap and low representation in high-level positions (BRAHNAM; KARANIKAS; WEAVER, 2011). According to *Guia de orientações sobre assédio moral e discriminação no ambiente de trabalho* (TJDFT, [2019]), (Orientation Guide on Psychological Harassment and Discrimination in the Workplace) of the Brazilian Court of Justice of the Federal District and Territories, discrimination can be understood as any distinction or exclusion based on gender, sexual orientation, religion, political or philosophical belief, race, or disability. Discrimination seeks to nullify or restrict the exercise, under similar conditions, of human rights and fundamental freedoms. It clarifies concepts such as mansplaining, gaslighting, manterrupting and bropriating. Mansplaining occurs when a man undermines a woman's knowledge and devotes his time to explain something obvious to her, as if she couldn't understand it on her own. Gaslighting is emotional violence that occurs via manipulation, leading the woman and those around her to question her sanity or think she is incapable. Manterrupting define situations when women are unable to complete their ideas due to unnecessary interruptions by men. Bropriating happens when a man appropriates a woman's idea and takes credit instead. Discrimination can lead to harassment, that is, any abusive, extreme, purposeful and frequent action that generates negative consequences for women's self-esteem, besides harming their dignity (BRASIL, 2009).

Several situations contribute to the gender gap in some fields. For example, women may be aware of the discrimination they may experience in a given field, making entry and progress in STEM careers more difficult. Cheryan *et al*. (2019) categorized other issues faced by women beyond perceived discrimination, such as gender devaluation, concerns about the possibility of stereotyping, lack of self-efficacy, low sense of belonging, romantic concerns, incongruence of goals, and fear of backlash.

Besides the physical and personality stereotypes women face when studying computing, common belief says that boys are more competent in the field. Thus, male students emphasize have their abilities emphasized (MIURA, 1987), even though, in practice, boys and girls generally have the same capacity (HARGITTAI; SHAFER, 2006). Besides believing more in their computer skills, boys also seek more support and encouragement from parents and friends (BUSCH, 1995). In fact, the stronger the identification with a gender role, the stronger the belief in self-efficacy, which is necessary for motivation (HUFFMAN; WHETTEN; HUFFMAN, 2013).

Women begin facing such issues at home, even before choosing a profession, due to cultural stereotypes. Their time in college is particularly challenging. Female computer science students can face decisive challenges in staying in the program, including lack of prior programming experience and a sense of isolation due to non-diverse classrooms. Consequently, female students may interrupt progress towards a degree and decrease their self-confidence in their ability to succeed in college and computing careers (DEKHANE; NAPIER; NAGEL, 2016).

Female students' low sense of belonging is a reaction to more depressing feelings of conformity to the stereotypes associated with computer scientists. This causes women's lack of interest and motivation in STEM fields (MASTER; CHERYAN; MELTZOFF, 2016). Studies show that the sense of belonging is an important predictor for college success (STRAYHORN, 2018) and is dependent on the environment that students frequent, which shows the important role of educators in promoting this feeling in students (SAX *et al*., 2018). A stereotypically classroom with gender disparities can result in a lower sense of belonging (CHERYAN; MELTZOFF; KIM, 2011).

Several programs worldwide sought to mitigate the absence of women in computing, such as the work conducted by Lund University, which sought to improve our understanding of campaigns for greater equality by seeking to comprehend the meaning, or meanings, of the #MeToo movement. The study examined how gender relations are expressed by women within IT. The campaign itself provided data showing that women are exposed to sexual assault and harassment within IT-oriented spaces (LINDGREN; ENEGREN, 2018).

This brief overview of the issues faced by women in computer science highlights the importance of a more in-depth understanding of this scenario. Seeking to unveil the main problems affecting women in computer science and how we can tackle them, we present in the next sections the method used and the results of our systematic literature review.

Method

A systematic review is a method of synthesizing evidence focused on one or more particular, well-defined questions, area of knowledge, or a phenomenon of interest

(KITCHENHAM; CHARTERS, 2007) that aims to gather, critically evaluate, and interpret all available and relevant data on the topic in a quantitative and/or qualitative manner. It is a rigorous methodology that applies explicit and systematic research methods, in which the procedures developed must be recorded at each moment, allowing replicability of the process.

Systematic review is a reproducible strategy for screening and including studies, and so it can be considered a secondary study that has primary studies—scientific articles that report first-hand findings—as its data source. Moreover, the systematic review also proposes to identify gaps in the literature and suggest future studies, besides help to inform practices and policies by providing unbiased and integrated evidence.

The present systematic review was elaborated using the reliable, rigorous, and auditable method proposed by Kitchenham and Charters (2007), which comprises planning and performing the review, and reporting the results obtained.

The steps applied during the development of this study include but are not limited to: identification of the need for a review; research design; preparation of review protocol; extraction, analysis and synthesis of data obtained in database searches; selection of primary studies; reading of selected papers to answer the research questions; and report writing.

Research questions

The gender gap in undergraduate computer science programs is clear. Despite the existing programs that encourage women to continue enrolling in university and the several reasons pointed out by the scientific literature to explain this scenario, some serious issue is often disregarded. Consequently, we must outline an overview of the problems identified as the causes of university dropout, as well as glimpse what has been done to solve this situation. To do so, we formulated the following key research questions:

- What are the problems faced by women in undergraduate computer science courses?
- What has been done to mitigate the problems pointed out in the scientific literature?

Database selection

Six online research databases were used: ACM Digital Library, IEEE Xplore, ScienceDirect, Scopus, Web of Science, and Springer. The databases were selected according to their visibility and importance in the areas of computer science and education.

Search strategies

We use two main search strategies: one to find systematic reviews on the topic and another to obtain related works to the present systematic review. The former was used to ascertain the originality of the study. To cover more papers, we combined keywords using the Boolean operators (AND, OR) as follows: (“undergraduate” OR “higher education”) AND (“gender” OR “women” OR “girl” OR “female”) AND (“systematic review”) AND (“computer science” OR “computing”) AND (“problems” OR “issues”).

The search was designed considering an extensive reading of the literature on women in computing, especially the book *Gender codes: Why women are leaving computing* (MISA, 2011).

To find studies to be filtered, we used the following search strategy: ("computing" OR "computer science" OR "technology") AND ("gender" OR "girls" OR "women" OR "female") AND ("issues" OR "problems") AND ("bullying" OR "chauvinism" OR "sexism" OR "harassment" OR "isolation" OR "segregation" OR "stereotype" OR "devaluation" OR "discrimination" OR "underrepresented") AND ("education" OR "students") AND ("undergraduate" OR "higher education" OR "university" OR "faculty").

Inclusion and exclusion criteria

During this research, we developed a set of inclusion and exclusion criteria by adapting established criteria used in earlier reviews, such as those by Ibañez and Delgado-Kloos (2018) and Akçayir and Akçayir (2017).

Inclusion criteria consisted of studies that:

- Indicated any problem faced by female computer science undergraduates;
- Suggested solutions to the problem mentioned;
- Pointed out the possible causes of the problem;
- Was available in full; and
- Was an empirical research.

Exclusion criteria comprised:

- Papers published in 2014 or previous years;
- Papers published in a language other than English.

We excluded duplicate articles before applying these criteria.

Study selection

Several articles report the choice of female high school students not to pursue careers in STEM fields due to gender discrimination, stereotyping, lack of representation, and even repulsion for exact sciences (VAARMETS, 2018). Some projects were created to combat this lack of female representation in computing, seeking to spark the interest of high school girls in pursuing a career in Computer Science (CHERYAN; MASTER; MELTZOFF, 2015).

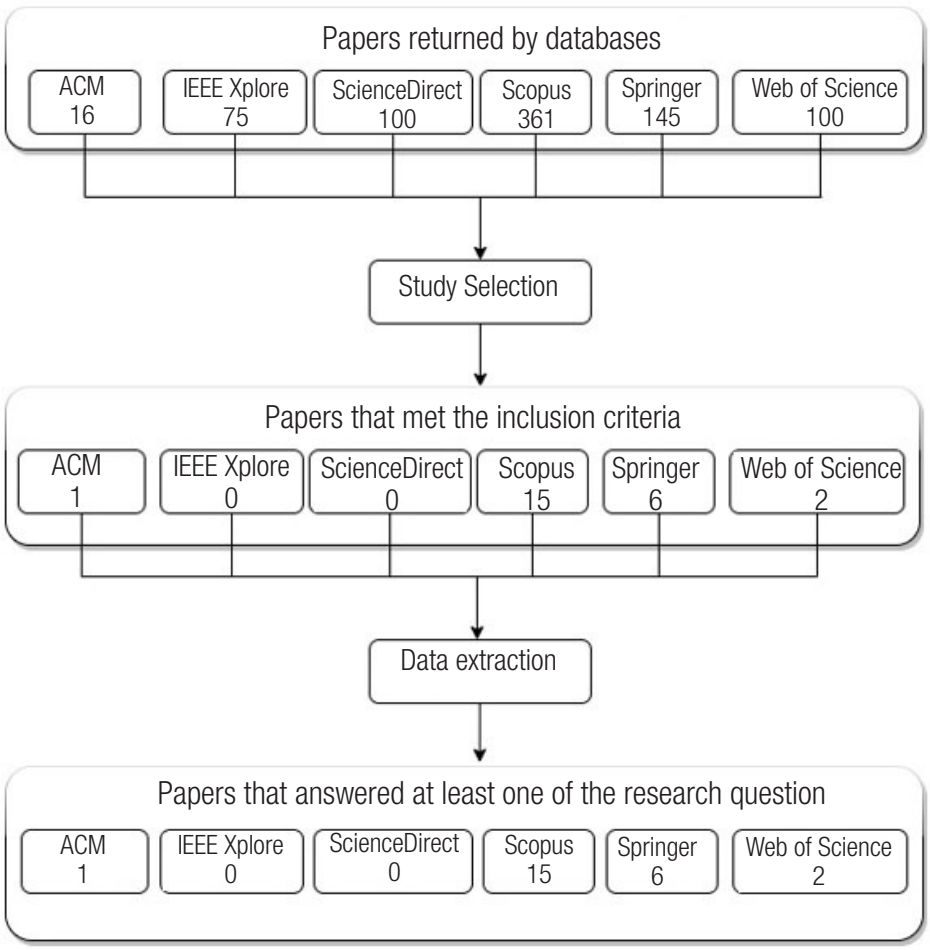
Many papers pointed out problems faced by all genders in the STEM academic environment, such as stress, depression, anxiety (BOEHM *et al.*, 2016), suicide ideation (PRUSTY; PANDA, 2017), and even the lack of didactic methods (RYOO, 2019).

Others presented the challenges faced by female university students in all fields, such as sexual assault, fear, and the fact that they do not seek help (HARRIS; TERRY; ACKERMAN, 2019). Despite being very interesting, these papers do not address specific

issues faced by female computer science undergraduates specifically, and were thus not accepted for data extraction.

The search strategy used returned a total of 818 articles from the six online databases. Fifteen duplicated articles were excluded. Only 24 works were accepted for data extraction. This reduced number of selected articles is due to problems with the indexing databases, which returned several articles outside our scope after the search strategies were entered. We only accepted papers that met the inclusion criteria. Figure 1 presents the flow chart of study selection and data extraction.

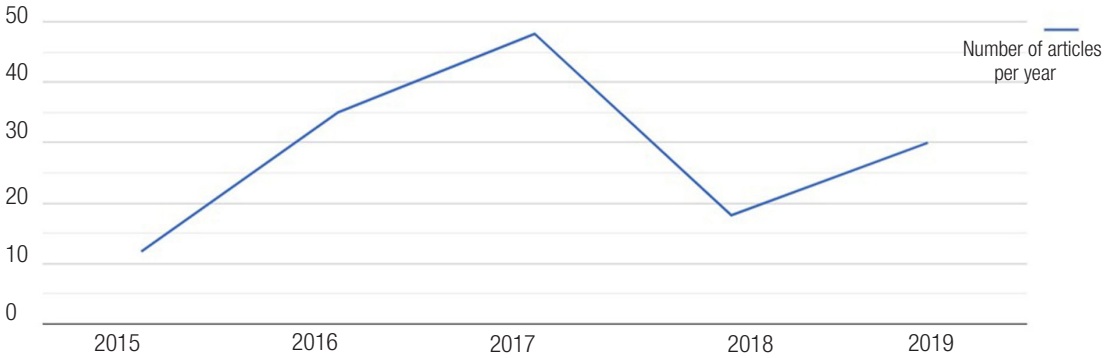
Figure 1 – Study selection and data extraction



Source: Prepared by the authors.

Figure 2 presents the articles accepted per year, after study selection and criteria assessment. We can observe that research on the topic under study had a substantial growth from 2015 to 2017, dropping in 2018 and increasing again from 2018 to 2019.

Figure 2 – Accepted articles per year



Source: Prepared by the authors.

Articles that met the inclusion criteria were cataloged by abstract, author, title, year, and journal. Papers addressing problems faced by female students in STEM were not excluded, since computing belongs to these fields.

The accepted articles were:

1. Balancing the equation: mentoring first-year female STEM students at a regional university (REID *et al.*, 2016).

2. Understanding student retention in computer science education: the role of environment, gains, barriers and usefulness (GIANNAKOS *et al.*, 2017).

3. Do you think you can? The influence of student self-efficacy on the effectiveness of tutorial dialogue for computer science (WIGGINS *et al.*, 2017).

4. STEMinism (MYERS; GALLAHER; MCCARRAGHER; 2019).

5. Computing and STEM in Greece: gender representation of students and teachers during the decade 2002/2012 (KORDAKI; BERDOUSIS, 2017).

6. A model of threatening academic environments predicts women STEM majors' self-esteem and engagement in STEM (CASAD; PETZEL; INGALLS, 2019).

7. Gender and student course preferences and course performance in computer science departments: a case study (IOANNIS; MARIA, 2019).

8. Closing the gaps and filling the STEM pipeline: a multidisciplinary approach (DOERSCHUK *et al.*, 2016).

9. College admissions viewbooks and the grammar of gender, race, and STEM (OSEI-KOFI; TORRES, 2015).

10. Swimming against the tide in STEM education and gender equality: a problem of recruitment or retention in Malaysia (GOY *et al.*, 2018).

11. Broadening participation not border protection: how universities can support women in computer science (MICHELL *et al.*, 2017).

12. Female undergraduate STEM persistence: a focus on the role of living and learning communities (NIX; ROBERTS; HUGHES, 2016).

13. Development and validation of the Value-Expectancy STEM Assessment Scale for students in higher education (APPIANING; VAN ECK, 2018).

14. African-American women's experiences in graduate science, technology, engineering, and mathematics education at a predominantly white university: a qualitative investigation (ALEXANDER; HERMANN, 2016).

15. Attrition of women in STEM: examining job/major congruence in the career choices of college graduates (XU, 2017).

16. Perceptions of male and female STEM aptitude: the moderating effect of benevolent and hostile sexism (REILLY; RACKLEY; AWAD, 2016).

17. Investigating gender issues in an undergraduate computing program (AMARAL *et al*., 2017).

18. The status of women in STEM in higher education: a review of the literature 2007-2017 (BLACKBURN, 2017).

19. Institutions developing excellence in academic leadership (IDEAL): a partnership to advance gender equity, diversity, and inclusion in academic STEM (BILIMORIA; SINGER, 2019).

20. Supports and pushes: insight into the problem of retention of STEM women faculty (PASCALE, 2018).

21. Gender in academic STEM: a focus on men faculty (SATTARI; SANDEFUR, 2019).

22. Starting at the crossroads: intersectional approaches to institutionally supporting underrepresented minority women STEM faculty (ARMSTRONG; JOVANOVIC, 2015).

23. Lesbian, gay, bisexual, transgender, and queer students' sense of belonging in computing: an intersectional approach (STOUT; WRIGHT, 2016).

24. Accounting for the role of policy in the underrepresentation of women in computer science (PATISAS, 2016).

Data extraction and analysis

After extracting data that answered the research questions, the authors' arguments were combined to cross-check that the ideas were not confusing or contradictory. Next, the data was summarized, integrated, and standardized. The methodological quality and limitations of the selected articles underwent content analysis – a thematic analysis focused on the relationship between content and context (ELO; KYNGÄS, 2008).

We defined a set of thematic categories and respective sub-categories according to the issues raised by the studies. The categories were effective in grouping studies according to their common characteristics. During the systematic review process, several sub-categories emerged, and others were refined to reflect the emerging information.

Results

Answering research question 1: What are the faced by women in undergraduate computer science courses?

The STEM academic environment has several problems that hinder women's academic achievement. Reid et al. (2016) point out aspects that female students enrolled in STEM courses at the University of New England perceive as possible obstacles to successful

progression in their STEM studies and careers: low confidence; education of children affected by structural prejudices, such as parents and educators teaching gender differences between toys, colors and behaviors; societal beliefs and expectations; gender bias; low sense of belonging; sexism and discrimination; sexual harassment; inherent differences between women and men; lack of female representation, information and support for STEM careers; and lack of job security. Another issue that can determine women's dropout from computer science undergraduate studies is the lack of family support and their perceived level of suitability between themselves and the environment (XU, 2017), which means having a low sense of belonging. Some findings confirmed that, among undergraduate and graduate computer science students, a low sense of belonging in the computing was associated with decisions to abandon their courses (STOUT; WRIGHT, 2016).

To organize and structure the various types of problems found in the studies analyzed, we outlined six categories (Table 1). We identified five problems that can lead to women's lack of sense of belonging on the campus environment: lack of representation, stereotypes, inadequate self-perception, gender bias, and indifference from others. The third column of Table 1 shows the numbers of papers that pointed to the problem category or subcategory. These numbers are the same as those shown in the "Study Selection" section.

Table 1 – Categories and subcategories of problems faced by women

Category	Subcategory	Article number
Lack of representation	- Underrepresentation; - Isolation; - Estrangement	1; 4; 5; 6; 7; 8; 9; 10; 11; 12; 13; 14; 15; 18; 19; 20; 21; 22.
Stereotype	- Third-party judgment; - Low self-esteem; - Fear of reaction	1; 2; 4; 5; 6; 7; 9; 10; 11; 13; 14; 16.
Self-perception	- Low sense of self-efficacy; - Low self-confidence; - Belief of poor ability; - Bad academic achievement; - Poor performance in subjects	1; 2; 3; 4; 5; 6; 7; 9; 10; 11; 13; 14; 15; 17; 18; 20; 22; 23; 24
Crimes and depreciation	- Gender discrimination; - Sexism; - Machismo; - Sexual harassment; - Devaluation	1; 4; 6; 9; 11; 13; 14; 16; 17; 18; 20; 21; 22; 23; 24.
Indifference	- Educational institution; - Colleagues and teachers; - Family and friends	4; 5; 6; 10; 17; 18; 23; 24.
Low sense of belonging	- Stress; - Anxiety; - Depression	1; 2; 4; 6; 8; 9; 10; 11; 18; 23.

Source: Prepared by the authors.

Lack of representation

Despite the increased number of women enrolled in STEM (not specifically in computing) subjects, this does not seem to extend to the retention of women in STEM courses and careers, with women and minorities remaining underrepresented in the field (BILIMORIA; SINGER, 2019; DOERSCHUK *et al.*, 2016; GOY *et al.*, 2018; MICHELL *et al.*, 2017; NIX; ROBERTS; HUGHES, 2016; OSEI-KOFI; TORRES, 2015). Many of those who do major in STEM drop out or change majors. More than 32% of female undergraduates who declare a STEM major are likely to switch to non-STEM majors before graduation, whereas only 25% of their male counterparts do so. Besides, women are 1.5 times more likely than men to abandon STEM fields (APPIANING; VAN ECK, 2018). The issues identified by Myers, Gallaher, and McCarragher (2019) are also related to a lack of female representation in the classroom—for example, having no or hardly any female professors—, leading to social isolation. Research on dropout rates among computer science students indicates that the most significant dropout point occurs in the first two years of university. Approximately 40% of those who begin a computer science course eventually leave without a degree, although this varies from about 30% to 60% depending on the institution (OSEI-KOFI; TORRES, 2015). Giannakos et al. (2017) argue that the high dropout rates in computer science education are a problem considering the growing demand for computing professionals.

Stereotype

Computing is seen as a male field, and stereotypes act as a barrier, subjecting women to low expectations of their abilities (MICHELL *et al.*, 2017). Influences from one's cultural and social milieu can stereotype one's occupational role (APPIANING; VAN ECK, 2018). Computing courses also have a reputation for being boring and not allowing students freedom and creativity (KORDAKI; BERDOUSIS, 2017). Sensitivity to gender bias led to more negative perceptions of the campus environment. In turn, a more negative environment produced more stereotypes, whose lack of control resulted in further disengagement from STEM fields and lower self-esteem (CASAD; PETZEL; INGALLS, 2019).

Self-perception

Women's sense of self-efficacy scores are lower than men's (WIGGINS *et al.*, 2017). The lack of female representation in computing has historically been associated, in part, with the belief that women are less confident in mathematics than men. But a recent study shows evidence to the contrary. In a nationally representative survey with university students, researchers showed that, while the self-concept in mathematics remains a relevant predictor for enrolling in STEM fields for men, it has become a less significant predictor for women (PASCALE, 2018). According to Kordaki and Berdousis (2017), loss of self-confidence affects women more than men and is a significant factor for women dropping out of Computer Science at all stages of the program. Women also do not

usually receive the same level of support as men from their social environment to enter and remain in Computing. Once women enter the field, however, they produce as well as men and perform better than them in their courses of choice. Studies conducted in Greece found no statistically significant differences between the average grades of male and female students in most curricular courses in the Computer Science department (IOANNIS; MARIA, 2019; MICHELL *et al*., 2017). Kordaki and Berdousis (2017) confirmed women's excellent performance in computing, but other research has stated that they have more difficulty in programming than men (RUBIO et al., 2015). The challenges faced by women in programming results from previous achievement-related experiences, for instance; typically, the first experience that boys and girls have with computers is through computer games, which are designed with boys, rather than girls, in mind. Nonetheless, we assume that if women choose computing courses, they can perform as well or even better than men. To date, no study has proved that women have less capable brains in exact subjects.

Crimes and depreciation

Due to gender discrimination and sexism, young girls who show interest in STEM careers are faced with challenges, such as sexual harassment (MICHELL *et al*., 2017), that can lead to problems in entering and remaining in STEM universities (REILLY; RACKLEY; AWAD, 2017).

Sexual assault against women on campuses is a problem in any field (HARRIS; TERRY; ACKERMAN, 2019). All the issues discussed so far can affect Black women disproportionally. Alexander and Hermann (2016) showed that African American women in STEM experienced racial microaggressions, sense of low self-efficacy, and lack of institutional support during graduate school at a predominantly white university. Moreover, Asian American students who majored in STEM were more likely to find a non-degree related job compared to white students. Conversely, white women in non-STEM majors were significantly more likely to have a job closely related to their major than women from minority groups (XU, 2017). Another significant factor to be considered are the abusive relationships women may have and get stuck in during university (MIN, 2019).

Indifference

How a campus addresses and deals with the problems faced by female students can also be a determining factor in their retention or evasion. Campus culture, classroom experiences, educational environment, sexist professors, lack of institutional support are some of the terms pointed out as serious problems by the analyzed studies. Myers, Gallaher, and McCarragher (2019) pointed to lack of faculty support as a cause of girls dropping out of STEM courses. Most students switch majors because due to poor teaching, harsh grading, and high demands common to these disciplines (GIANNAKOS et al., 2017). Another circumstance that hinders students' development more generally is poor pedagogy (OSEI-KOFI; TORRES, 2015). Sattari and Sandefur (2019) argued that the egalitarian academic structure does not allow gender to have a significant impact on achievements in STEM.

Low sense of belonging

Reid *et al.* (2016), Giannakos et al. (2017), Myers, Gallaher, and McCarragher (2019), Casad, Petzel, and Ingalls (2019), Doerschuck et al. (2016), Osei-Kofi and Torres (2015), Goy *et al.* (2018), Michell *et al.* (2017), Blackburn (2017), and Stout and Wright (2016) pointed to low sense of belonging as a consequence of all the problems faced by women on campuses. Feeling as if they do not belong to the place they frequent generates anguish, stress, anxiety and even, in some cases, depression. Consequently, these authors see the dropping out of computer science courses as a way of evading such problems.

Answering research question 2: What has been done to mitigate the problems pointed out in the scientific literature?

To mitigate some of the issues problems pointed out in the section above, Reid *et al.* (2016) proposed a mentoring program designed to help female students develop STEM-related study and career goals by having two mentors—one academic and one industry-based. This program could be readily adapted for all students embarking on STEM studies. According to the authors, the program helped female students understand and address potential barriers to a successful STEM career, build confidence in their study goals, and develop career skills. The academic mentors reported a positive impact on their approach to STEM teaching as a result of participating in the program.

To minimize the effects of a sense of low self-efficacy in female students, Wiggins *et al.* (2017) examined a corpus of human tutoring to discover the extent to which self-efficacy measured in a pre-survey, in conjunction with dialogue and tasks during training, promotes models that predict female students' self-reported frustration and learning gains after tutoring. Tutorial dialogue practices that engage female students in dialogue with natural language can create productive and adaptive interactions. Social dialogue and moves by the tutor to increase efficiency may be particularly helpful for students with high self-efficacy. Guided experimentation may promote greater learning for low self-efficient students, but at the same time it can potentially increasing frustration. There is no one model tutoring system to be followed strictly; tutoring must be developed according to the needs of each student.

After applying a questionnaire to female undergraduate STEM students, Casad, Petzel, and Ingalls (2019) developed a model that illustrates how aggressive events may contribute to the underrepresentation of women in STEM. The model provides a better understanding of the relations between hostile STEM climates, identity threat experiences, and academic disengagement. Their results highlight psychological and educational variables that predict women dropping out of STEM, which is useful information for preventing the decline of women in STEM majors.

Several Australian universities participated in the launch of Respect. Now. Always, a poster campaign—and subsequent survey administered by the Australian Human Rights Commission—by Universities Australia focusing on the rights of all students to be safe, free from sexual violence and harassment. This action was undertaken to support victims of sexual harassment on campus (MICHELL *et al.*, 2017).

Bilimoria and Singer (2019) described the objectives, activities, and results of the ADVANCE project, overseen by the National Science Foundation, a group of institutions that promote excellence in academic leadership (Ideal). Ideal's goal was to develop and leverage knowledge, skills, resources, and networks to transform academic cultures and enhance gender equity, diversity, and inclusion in STEM disciplines at Ohio universities. Over three years, these institutions have developed academic leaders and built traditional gender equity by means of multidimensional, multilevel initiatives, improving the advancement and leadership of the female body in these disciplines.

The remaining papers made no mention of initiatives, but contributed by investigating the female students' problems and/or perceptions.

No solution to the problems faced by women inside the classroom was found. Amother limitation observed was that all the solutions proposed focus only on the women, ignoring the importance of raising awareness among male colleagues and professors. No attempt was made to foster dialogue and collaboration between students and between professors and students to increase empathy towards women. The initiatives proposed to mitigate problems like low self-efficacy and sexual harassment will be briefly explained and have their impact assessed below.

Discussion

All the issues discussed by the papers analyzed lead to the women's low sense of belonging in the computer science environment, making them feel isolated and demeaned. Cultural problems such as machismo are responsible for instilling low self-esteem in female students. Low confidence begins to be built in childhood and stems from their experiences with family and friends. Many family members do not believe that women suffer any aggression because they are women; they strongly assert that if a woman is as good as a man, she will be equally respected. Unfortunately, however, women require help and encouragement to achieve an excellent technological level in computing, for even at home they face discrimination and social stigma. Pretentious judgments and statements like these further increase women's low self-esteem, as if the responsibility for being treated differently or receiving lower wages was all theirs. Studies show that, depending on how girls are raised and their developed cognition, they may develop difficulties in some subjects or believe that they incapable of completing challenges in computing. Soon their beliefs about their abilities are impaired, leading to low self-confidence and low self-efficacy. Women may therefore experience difficulty in some subjects such as programming, and often poor didactics, peer discrimination, and lack of confidence are serious factors that lead them to abandon university and their careers.

The few women found in computing and on-campus reflcts on the minimal number of female professors and students. This scenarion can inhibit or even lead to the isolation and estrangement of the few women who remain. Unfortunately, as shown by many papers, gender segregation is cultural and changing the culture is a complicated endeavor. The fewer women in computing, the fewer girls become interested in computer science. The lack

of female representation in computing leads to the abandonment of the field. Many studies have pointed out the lack of interest of high school girls in entering computing, but the lack of female representation in the field is also responsible for the dropout of girls who, at some point in their lives, tried to be part of it. This lack of interest is often not because women dislike or are not curious about technology, but because they rather not face gender stereotyping and isolation, as well as fear of not being salaries the same as men.

The stereotype of women persuing a computer science degree is the perception others have of them. Society sees women who study computing as strange and unfeminine people who lacking a good appearance. Women in STEM also face many judgments about their personality and how they live their lives. All this pressure leads women to develop low self-esteem and fear people's reaction when declaring their major. Another problematic differentiator is that women and girls are more likely to be victims of crimes such as sexual harassment and sexual assault stemming from machismo. Their chances of hearing sexist jokes on campus or experiencing gender discrimination are high. Also, the burnden of motherhood is often much heavier than that of fatherhood. Female students who have children are judged because, according to society, they should spend all their time taking care of their children and not studying or working, while the same is not required of men. Often, women stop advancing in their professional careers to exclusively take care of their children. Hence, students who are mothers have a great potential to give up their careers for lack of support.

Although they are of paramount importance, the initiatives discussed in the "Answering Research Question 2" section focus solely on increasing women's confidence and interest in Computer science. While change is still up to women, there needs to be real support, and we must enhance respect and empathy from everyone on campus. The initiatives presented have a small-scale, local impact and are difficult to implement on campuses. It is essential that measures within the classroom and on campus are taken to support female computing students. If women are actively recruited, and if classroom dynamics are deliberately adjusted to encourage their sense of belonging, female students are more likely to enter STEM fields and stay (MYERS; GALLAHER; MCCARRAGHER, 2019). Cognitive gains and supportive environments positively affect permanence, while non-cognitive gains hinder it. Institutional neglect and the indifference of professors and colleagues only make matters worse, leaving the women alone "against the world," who often lack support from those who should take care of them most—family and friends.

Awareness-raising campaigns, student support training, guidance from parents and guardians, improvement in teaching didactics, and projects that include women and motivate them in computing are examples of positive attitudes to be taken by educational institutions. Besides the aforesaid initiatives, in-class initiatives are essential to mitigate the issues faced by female undergraduate students. This systematic review is relevant for such educational interventions, providing information on the main problems faced by female students in computer science courses. Our results can help in theoretically-based academic, managerial and administrative decision-making processes regarding gender issues.

Conclusion

This systematic literature review on the issues faced by female computer science undergraduates examined the key reasons reported for career abandonment. It sought to highlight the main problems that must be overcome within university campuses and within the classroom, as well as to identify the limitations of the proposed solutions.

We found few specific studies on the problems faced by women in computer science on campus and especially in the classroom. Female student dropout in computing results from a low sense of belonging caused by lack of representation, negative gender stereotypes, low sense of self-efficacy, gender depreciation, and indifference of counterparts. These problems can disproportionally affect Black, Asian, and queer women.

The job market sees team diversity as a significant factor in better serving customers, just as colleges have an interest in retaining students. Consequently, some initiatives have been developed to mitigate those issues. But these initiatives have a local and temporary effect, being difficult to implement on other campuses and not guaranteeing the long-term permanence of women in computing fields. There is a demand for more effective initiatives to encourage women to persevere in undergraduate computing courses.

Pointing out the main problems experienced by female computing students and identifying the limitations of initiatives taken to solve them, is the first step for future research to propose good ways around them and to outline specific solutions within the classroom, that raise awereness of such issues among educators and even classmates. Attention to these issues may spark the interest of researchers in working to make undergraduate female students' experiences while pursuing a STEM degree more positie, decreasing the chances of dropout. With the knowledge and understanding of the problems discussed by this systematic review, further research should focus on actions to mitigate or prevent such issues.

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