Eliminating Gender Bias in Computer Science Education Materials

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ABSTRACT

Low female participation in Computer Science is a known problem. Studies reveal that female students are less confident in their CS skills and knowledge than their male counterparts, despite parallel academic performance indicators. While prior studies focus on limited, apparent factors causing this lack of confidence, our work is the first to demonstrate how, in CS, instructional materials may lead to the promotion of gender inequality. We use a multidisciplinary perspective to examine profound, but often subtle portrayals of gender bias within the course materials and reveal their underlying pedagogical causes. We examine three distinct samples of established CS teaching materials and explain how they may affect female students. These samples, while not a complete display of all gender inequalities in CS curriculum, serve as effective representations of the established trends of male-centered representation, imagery, and language that may promote gender inequality. Finally, we present easily implementable, alternative *gender equitable* approaches that maximize gender inclusion.

CCS Concepts

•Social and professional topics → Computer science education;

Keywords

Gender, Diversity, Confidence, Gender Equitable

1. INTRODUCTION

Trends of gender inequality have long affected the field of CS, across all levels. Perceptions of a masculine environment and notions regarding 'nerd culture' continue to deter women from entering the field [12]. Even amongst women who do transgress these stereotypes and enter CS, low confidence tends to characterize their educational experience [12, 5]. Despite performing as well as men, women consistently believe they are performing at lower rates [4, 12].

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Factors believed to cause low confidence include low female participation, faculty belief that diversity initiatives lower standards [5], and stereotypes that women are naturally less skilled at computing than men [10]. While previous studies discuss the discrepancies in student confidence levels, to the best of our knowledge, our study is the first to take a deeper examination of the ways that gender inequality and stereotypes are conveyed through specific course materials. Although low female participation and unequal access and attention from faculty have been documented as some causes of low confidence [5], specific ways in which faculty may reveal their biases of inequality toward female students, were unknown. Thus, we found trends in the methods and materials used in CS classes that can reinforce harmful stereotypes about women.

We examine three distinct examples from various fields of CS to show ways in which current pedagogical approaches may project unfair gender biases. We discuss in depth why and how stereotypes about women can manifest themselves through class materials. Awareness of these biases can influence educators to more carefully select their methods for presenting information. We believe that increased awareness and our recommended changes will lead instructors toward methods that maximize female inclusion and overall gender equity. We propose *Gender Equitable Approaches* that favor the inclusion of all students. These approaches are widely applicable, recommended alternatives that instructors and material creators can use in a wide range of courses and levels. The greater impact of our work is to promote equitable changes in the way CS materials are created and shared, beyond the three examples we provide.

In the following Section, we demonstrate inequalities in course materials, and describe how to eliminate them through three examples: *Representations* of Gender, Stereotypical *Imagery*, and Male-Centered *Language*.

2. APPROACH

2.1 Representation

The first example we evaluate is the classical teaching example that is generally used to introduce and explain cryptographic protocols in upper-level computer security courses. Nearly all security textbooks and papers describe cryptographic protocols through these character representations to help students understand the concepts. The method is based on "Alice sends a message to Bob," and is developed with more characters. As new research emerges, new characters form, and their roles vary to demonstrate the material. This example is particularly applicable since it is set

Table 1: Summary of the cryptographic protocol characters, showing their gender and the connotation of their role (Key: (F) Female; (M) Male; (Mix) Both; (+) positive connotation; (-) negative connotation; (/) No associable connotation).

Name	Alice/ Bob	Carol	Chuck	Craig	David	Erin	Eve	Fayth	Frank	Grace	Heidi	Mallory	Oscar	Peggy/ Victor	Plod	Sybil	Trent	Trudy	Walter	Wendy
Gender	Mix	F	M	M	M	F	F	F	M	F	F	F	M	Mix	M	F	M	F	M	F
Connotation	/	/	-	-	/	/	-	+	/	-	-	-	-	/	+	-	+	-	+	-

in an adversarial environment. This makes it effective to teach computer security concepts, including attack scenarios, defense, and mitigation solutions. Although these representations are useful tools for conceptualizing material, we demonstrate that they elicit negative stigmas of women in CS through biased naming practices.

2.1.1 Contentious Naming

Each character has a name and role that places them in the context of cryptographic protocols. Once named and shared by a given scientist, the names tend to become the standard for consequent papers and teaching materials.

The names and associated roles of the characters in the classic teaching method are problematic due to their unfair distribution of positive and negative roles for males and females. For example, the most well known attackers are Eve and Mallory. Eve, the 'eavesdropper,' attempts to invade privacy by eavesdropping the message between Alice and Bob. Evidently, both of the most well-known adverse characters, are female. Mallory, another character, is the perpetrator in the man-in-the-middle attack. Grace, whose name implies pleasant meaning, is in fact a government representative with negative connotation because she tries to force the implementation of backdoors into cryptographic protocols. On the contrary, characters such as Trent the 'trusted arbitrator' and Walter the 'protective warden' clearly have positive connotations and are given male names. The first letter of a character is often associated as the arbitrary reason for giving a character their name, such as in trusted Trent. Nevertheless, Wendy the 'whistleblower,' a rogue insider that divulges private information, is given a female name, despite sharing the same first letter as Walter the warden. Similarly, Eve the eavesdropper could have been arbitrarily named Evan, and Grace from the government could have been Gary, for example. Hence, the skewed assignment of names indicates a bias of negativity toward the role of females in Computer Science, eliciting stereotypes that place women in the role of antagonists, and males as protagonists.

Furthermore, not all names are assigned based on the first letter of the name and respective role. 'Sybil,' another cryptography character, is named after 'Sybil attack.' This representation describes an attack in which identities are forged to subvert a reputation system in peer to peer networks [16]. The name was inspired by the book "Sybil" about the treatment of a woman diagnosed with dissociative identity disorder as a result of physical and sexual abuse. The representation of a mentally ill woman as the field standard term for an attacker is not only insulting, but harmful, by projecting negative stereotypes about women. Social psychologists argue that such stereotypes can elicit impressions and expectations of members of the stereotyped group [6] which hinders women's academic performance [22] and confidence [6]. Moreover, it is noteworthy that Sybil attack was not the first, and not the only term used to describe this attack; the term "pseudospoofing" [16] was used before Sybil Attack was introduced. Nevertheless, it was not adopted by the scientific community as the standard term, despite being coined prior to Sybil, and its more intuitive relation to the attack. This demonstrates the extent to which representations in CS are predominantly male-centered.

By comparing characters with positively or negatively associated roles, we found clear gender discrepancies (Table 1). There are more female characters than males. However, this does not indicate fair inclusion. In fact, of the four characters with positive connotation, only one is female. By comparison, of the nine total negative roles, six are female and three are male. Thus, of eight female associable characters, less than 13% of them are "good" compared to 50% of associable male characters.[1] The implications of this study suggest strong gender biases in the traditional representations that teach cryptography.

2.1.2 Implications

The institutionalization of negative representations of women in CS demonstrates a severely unbalanced male influence in the field. Since CS has long faced a shortage of women, it is unsurprising that the materials reflect predominantly male-centered perspectives. This results in continuous generations of students learning from materials that are rooted in inequality. Subsequently, they will continue to use and advance the field using the biased standardized materials, forming a vicious cycle.

2.1.3 A Gender Equitable Approach

To eliminate biased representations of gender, we theorize changes that can be applied to the cryptographic protocol characters, and can be extended to other CS materials. It is critical that any changes made will retain the whimsical, relatable, and educational qualities offered by the classic approach. An obvious solution one might consider is the substitution of current names with gender-neutral names, such as replacing Alice and Bob, with Alex and Brinn. However, this would provide only marginal improvement, because gender neutral names still elicit highly variable associations of gender [23]. Only one reference [17] recommends an alternative to the use of Alice and Bob, with no regard to equality. They propose using Hindu mythology characters. However, this example does not minimize gender inequalities. Rather, it may hinder student's understanding, particularly if they don't have background in Hindu mythology, since the names

[1] 2/10 female and 2/8 male characters do not have associable connotation. Thus, they are not addressed in the analysis.

are parallel to mythological roles. Thus, we constructed an approach that effectively yields gender equity: replacing the characters with animals. For example, we replace Eve the 'eavesdropper' with an owl who 'watches,' and Sybil, who assumes numerous forged identities to launch this form of attack, with a chameleon that changes colors and assumes varying identities. Mallory, the perpetrator in man-in-the-middle attacks, is replaced with a sneaky snake.

The use of animals never detracts from the learning experience, but equalizes it. Also, due to the universal nature of animal representations, educators from different cultural and language backgrounds can use this method to teach their students in a relatable way. Similar changes could be made across a wide range of CS materials to easily and effectively eliminate gender bias.

2.2 Imagery

In this Section, we examine the use of imagery as a source of gender inequality in the classroom. To illustrate this idea, we present a specific example of a test image, Lena, that has been overwhelmingly used in Image Processing. We discuss the negative implications of using such imagery in CS classrooms and present gender equitable alternatives.

In 1973, a researcher tore a centerfold image of an exposed woman from Playboy Magazine, cropped it at her bare shoulders, scanned it, and used it for a research paper on Image Processing. Since then, the image of Lena has become the industry standard stock image, not only for Image Processing, but numerous fields and many established large software projects that require the use of a test image [2].

The premise of Lena's popularity is based on her physical qualities. IEEE former editor-in-chief explains, "the Lena image is a picture of an attractive woman. It is not surprising that the (mostly male) image processing research community gravitated toward an image that they found attractive [15]." Despite its popularity, the use of a lewd image as the industry standard is problematic. Such imagery objectifies women by projecting stereotypes that emphasise their physical appearance rather than mental values. Objectifying imagery affects women's confidence, and therefore academic performance, in two ways: deteriorating their perceptions of self, and lowering other's perceptions of them.

2.2.1 Perceptions of Self

Psychologists have extensively documented that the physical objectification of women's bodies causes them to internalize emphasis on sexualization, resulting in reduced cognitive performance [14]. Moreover, Gervais et al. [9] specifically show that women performed more poorly in math after being exposed to the objectification of another woman. Also, exposure to stereotypes in the classroom negatively affects student participation and success [22, 5]. Even when women do not believe in the stereotypes, the very acknowledgement that the stereotype exists, and the cuing of the stereotype, lowers women's academic performance [12, 22]. Objectification also causes women to reduce their levels of communication [11]. This can be particularly detrimental in a classroom environment that should encourage student participation. Therefore, we see that images like Lena can have serious negative consequences on women's confidence through the way they perceive their own values.

2.2.2 Perceptions by Others

Objectifying images also affect the way that others perceive women. Regardless of gender, studies show that overall, objectifying images result in both men and women associating less positive attributes to the female gender. For example, when male and female subjects were shown images of women whose physical qualities are emphasized, people associated them as having reduced competence levels [11]. Also, studies show that women are perceived as less intelligent, when they or even other women, are objectified [13]. Since objectifying images lower people's perceptions of women, we can infer that exposure to images like Lena, in the classroom setting, lowers the value that faculty and students alike place on the values of women, particularly their intellectual values. This is significant because prior studies show that faculty expectations of women directly influence women's achievement in the CS major [5, 24].

2.2.3 Implications

The combination of women's lowered perception of self, with the lowered expectations from others can cause them to lower their rates of participation, question their abilities, and even discontinue their role in the field. Hence, we infer that objectifying imagery reduces women's confidence. Irani [12] explains that women's confidence is key to establishing an 'identity of competence' in CS. Not establishing this may deter them from continuation of CS studies. Other evidence suggests that, in CS, female students' confidence has a direct impact on their likelihood to pursue further education and challenge themselves academically [5]. The use of harmful images, such as Lena, is a precise example of how CS materials, and the educators who use them, perpetuate harmful perceptions of females, without intending to do so.

2.2.4 Case Studies

The following accounts describe women who experienced lowered self-confidence, academic distraction, heightened feelings of exclusion, and objectification, from exposure to the image of Lena.

In a Washington Post column published in 2015 [25], a female student shares her experience when given an assignment to look up the image of Lena and use it as a sample image for a project, "[I was] struggling to believe that I belonged in a male-dominated computer science class. I tried to tune out the boys' sexual comments...as a result, some young women are deciding not to pursue upper-level computer science courses."

Similarly, professor of CS, Deanna Needell, describes her experience as a CS student first exposed to the image of Lena, "I was literally the only female in this classroom with 30 men. They open their textbooks and there's Lena, and all the men start giggling. You just feel like, 'Oh, my gosh, this woman is being materialized (in a textbook)...' " [1]. In response to this uncomfortable experience as a student, Needell and her colleague published a paper in the field of image processing in which they subtly replaced the traditional image of Lena with an image of a male model. Similar to the Lena photo, it shows him exposed and cropped at the shoulders [1]. Although this image replacement draws attention to the issue of female objectification in CS, it does not reduce the inequalities between men and women. Replacing an exposed female with an exposed male simply shifts the materialization of a human in a textbook from female to male objectification. We argue that an effective classroom

should never objectify members of any gender, but rather strive to maximize the inclusion of all students.

2.2.5 Gender Equitable Imagery

In order to eliminate gender bias and promote the inclusion of all students, a suitable replacement for images like Lena must be implemented. One approach offered in the field of Psychology has been the replacement of objectifying images, with positive ones. Studies show that the placement of an empowering image, such as a woman holding a trophy, may counter existing trends in objectification, and that the promotion of positive imagery of women may also diffuse objectification [7, 11]. Also, seeing counter-stereotypical images of women, such as in leadership positions, results in women expressing positive ideas about their gender [7].

However, our recommended approach is to replace field standardized images with known monuments, such as the Aztec Pyramids or Persepolis Parseh. Similar to the replacement of representation in cryptography animal characters, the neutralization of the image processing standard image would eliminate gender bias and the commodification of women in textbooks. This is the most equitable solution because it does not favor portrayal of either gender, or even race. Only in cases that absolutely require the use of a facial test image, we recommend the use of an empowering female image, which counters objectification, as described by psychologists. Overall, replacing the image of Lena with either of these substitutions would only promote inclusion, while maintaining full scientific value as test images. While one might argue that the Lena image contains some features suitable for testing various image processing algorithms (e.g., a mixture of detail, texture, and shading), these traits are not exclusive to this image. In fact, any image with these characteristics can be used and tested without great effort. Considering the immense array of images available with today's technology, there is simply no reason to continue to use an image that provokes objectification, manifests stereotypes, and lowers female student's self confidence.

2.3 Language

In the English language, there is no singular pronoun that refers to both *he* and *she*. Thus, writers and speakers must make a choice about how they will address unspecified people: *he, she, he or she,* or the singular use of *they*. In this section, we discuss the negative implications of using male-oriented generic pronouns in the context of CS lectures and course materials. We selected three CS books of varied topics that demonstrate how educational writers vary in their pronoun choices, and discuss the effectiveness of each approach. Last, we offer a gender equitable alternative to the use of the generic *he* and the male-oriented *he or she* pronouns.

2.3.1 The Generic He

Scholars of Applied Linguistics have long denounced the use of the generic *he* because it reinforces and perpetuates gender inequality. Many investigations have supported this argument, and demonstrated that the use of the generic *he* invokes male bias in a significant proportion of subjects [18]. Specifically, studies on university students support this argument by showing that both male and female students produced substantially more mental images of men than women, when cued with the generic *he* [8]. This is particularly applicable in CS, since it is already known to be a male-dominated field. Therefore, when an instructor uses words like *he or she* or simply *he* as gender-inclusive pronouns, students are even more likely to associate that pronoun with a male.

2.3.2 Pronouns in Computer Science Education

To maximize gender equity and minimize stereotyping, it is vital to neutralize the language, and specifically, pronoun choice, that is used in class. Furthermore, an analysis of pronoun choice amongst teachers reveals that many instructors model their pronoun choice on the way their university instructors lectured [8]. Thus, mindful instructor linguistics at the university level are key to promoting linguistic equality in various levels and across generations of CS classes. Without proper awareness of language bias, it is easy for instructors to project inequality. For example, mental image of a noun affects pronoun choice [18], which can influence educators to use *he* for 'scientist' or other typically masculine nouns. This can lead to unintended, biased portrayals of women. To demonstrate, the following passages are taken from Bruce Schneier's book, "Secrets and Lies: Digital Security in a Networked World" [21], which explains computer security in a straightforward manner:

> "The problem is this: Anyone, no matter how unskilled, can design a cryptographic primitive that he himself cannot break. This is an important point." (pg. 116)

> "...He's already inside the system he wants to attack, so he can ignore any perimeter defenses around the system. He probably has a high level of access, and could be considered trusted by the system he is attacking." (pg. 47)

Notice that both examples use the generic *he* and thus assume that the subject is male. Also, both subjects are hackers and advanced computer users. Compare these examples to some of the few female examples provided:

> "A hacker would have simply counted his wife's teeth. A good hacker would have counted his wife's teeth without her knowing about it, while she was asleep." (pg. 43)

> "Let's start with an analogy. In order to steal something from your local 7-11, you're going to have to get past the sales clerk. This clerk isn't a creative thinker. In fact, she will only do what her employee manual says she's supposed to do... She gives us all the money in the register and turns to the next page. We can tell her we don't want to buy anything, and leave. If the 7-11 clerk is really as dumb as a computer system, we can get away with it... By slipping a page into her employee manual, we can give her arbitrary instructions." (pg. 207)

In comparison to the male examples provided, it is very clear that the females are less positively portrayed. In fact, the first example reinforces stereotypes by defining the role of a woman as relative to her male spouse (who in this case is a hacker). By using the generic *he*, the author assumes that the hacker is male and the generic spouse, is female. Also,

the second passage suggests that women are not intelligent, are not creative thinkers, but are easily tricked. Although the author surely did not intend to include such biases in the text, this demonstrates how the use of the generic *he* invokes stereotypes. Without intention, such biases reveal themselves in teaching materials, particularly when the field is already male-dominated. In fact, studies show that men use the generic *he* more often than women, specifically in academia [18]. Although "Secrets and Lies" does include *some she* pronouns to refer to hackers, users, and programmers, the overwhelming majority use the generic *he*, implying that women have less intellectual worth.

Nevertheless, we found several other books containing indications of attempts to convey language equality in CS materials. While they do not completely eliminate linguistic gender bias, they are positive examples of the ways in which CS educators can write material to include fair depictions of women. For example, a widely used introductory textbook, "Absolute C++" [20], uses the pronoun *he or she* for all examples in which a generalized person is referred to. The one example in which a specified pronoun is used is interesting; the name of a fictional character by the name of "Joe," a traditionally male name, was described as *she*. Joe does not have positive, nor negative connotation associated with her role, but nevertheless the author attempts gender equity through this balanced approach. Although the author did not use any gender specific pronouns to create unfair bias toward men, they present stylistic quotes at the beginning of chapters from literature that does use the generic *he*. The two examples are, "He who would distinguish the true from the false must have an adequate idea of what is true and false." Also, "Once a person has understood the way variables are used in programming, he has understood the quintessence of programming." These quotes, particularly the latter, are problematic because they place the role of 'capacity' and 'understanding' onto males. The second quote is especially misleading because it invokes two assumptions: first, the assumption that someone who is a 'person' is male. Second, that if a 'person' is a programmer, they are male.

Another example of how authors mitigate gender bias in CS is demonstrated in "Computer Security: Principles and Practice" [3]. Like the previous author, this author also made clear attempts to be gender equitable by referring to unspecified people as *he or she* in every possible example. However, this book presents a different tool for scenarios in which a single individual is distinguished; alternating between examples in which the agent of action was a female, and male. Therefore, both genders were equally represented in examples. We noted that, unlike the Scheier text, these examples did not have distinguishable positive, nor negative associations relative to each other, making it simpler to fairly assign roles.

2.3.3 Gender Equitable Language

To improve the tone of the materials to reflect gender equitable perceptions of women in CS, we propose that simple changes be made by instructors and authors of teaching materials.

The first steps in eliminating gender bias in language are awareness of the inequalities that exist, and making conscious efforts to use gender equitable language. Once instructors have decided to make this effort, they have some options. One linguistic approach offered by the field has been the alternating of *he* and *she* throughout a given material [19]. However, this has the potential to leave too much subjectivity to the original author or presenter to insert their own gender biases, as demonstrated in the example of the Scheier text.

As shown in Absolute C++, another method is the use of *he or she*. Although this is indeed a generic pronoun; and the most widely used pronoun among educators and academics [18]; it is not the most effective method of eliminating gender bias. Studies show that the use of *he or she* invokes different images for men than women. Men mostly produce images of males, and very few images of females, almost exactly as invoked by the use of the generic *he* [8]. Women, on the other hand, mostly produce images of females, and few of males [8]. Since men and women do not produce even distributions of male and female images, the use of *he or she* does not truly eliminate gender bias.

Thus, we propose the use of the singular pronoun *they* to refer to nouns with unspecified gender. Take the example of the quotes provided in Section 2.3.2; if one simply replaces *he* or *she* with *they*, and *his* or *hers* with *theirs*, the meaning of the text remains unchanged, but the implications of the text no longer reflect gender bias. Studies demonstrate that the use of the singular *they* has increased in popularity over time and has become an acceptable neutral pronoun [19, 18]. Some educators already use the singular pronoun *they* for a variety of reasons, including its simplicity compared to its longer alternative: *he or she* [19]. Also, both male and female students respond more neutrally to *they* than *he or she* [8]. In fact, *they* is the generic pronoun that elicits the most even distribution of male and female images [8]. For women, *they* is completely a generic pronoun, and for men, it is much more generic than *he or she* [8]. Hence, the use of the singular *they* is the approach CS educators should take to eliminate gender biases in materials and presentations. All educators can benefit from this small change. Writers can reduce or completely eliminate gender bias in their text. Likewise, instructors can easily implement these changes into their verbal and written communications with students.

3. DISCUSSIONS

The intersectionality of gender and race is a force that merits full recognition. While our focus in this paper is based on gender and prior studies on gender and education, we also believe that our alternative solutions to the existing issues in CS pedagogy can increase overall student inclusion, such as students of color, particularly women of color. For example, we believe that by eliminating names like 'Alice' and 'Grace,' the teaching materials will be less biased toward white (naming) and therefore, white culture. Furthermore, eliminating the use of images like Lena particularly enhances the classroom experience for women of color by removing the institutionalization of white beauty as a standard, from classrooms.

Furthermore, while we recognize that our samples and solutions described Section 2.3, *Language*, apply uniquely to the English language, we emphasize that it is most important to first set the scientific standardized language on a path to correction of its gender bias. Once implemented, this can establish a model for other countries' CS scholars to improve the use of pronouns in their languages as well.

4. PRELIMINARY EVALUATION

At California State University, Northridge, we conducted an informal evaluation to compare the traditional teaching method of using cryptography protocol characters to our gender equitable alternative in a computer security class. We implemented the alternative of animal characters, as introduced in Section 2.1.4, and described the animal interactions through the use of the singular *they*, as explained in Section 2.3.4.

Each method, traditional and gender equitable, was used in two separate classes to form the control (n=31: female=5, male=26) and experimental (n=38: female=9, male=29) groups. At the end of the course, we measured the students' confidence in both groups. Specifically, we asked each respondent to express agreement/disagreement to the following statement: *"I am confident that I understand how the cryptographic protocols presented in the class, work."* We asked them to respond to this on the Linkert-scale (5-point agreement scale; 1= "strongly agree," 2= "somewhat agree," 3= "neutral," 4= "somewhat disagree," and 5= "strongly disagree"). Then, we compared male and female student responses. Our preliminary evaluation, as summarized in Figure 1, indicates an improvement for female students' confidence in understanding the material. Since the male responses did not experience significant change across both evaluations, our alternative solution did not negatively affect male students.

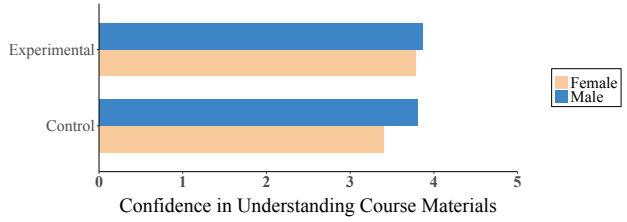

Figure 1: Student confidence ratings for traditional (control) and equitable approaches (experimental).

There are parameters that can be best captured through only long-term assessments. By developing a long-term study, we can examine more variables, such as retention, withdrawal, and changes in field. We will also more thoroughly measure both attitude and confidence levels toward the subject matter through pre-test and post-test surveys. Additionally, we will compare students' average final grades to see if the gender inclusive teaching methods we used have any effect (positive or negative) on understanding the material. These grades, while not a perfect measure for student learning, should indicate whether students were able to learn the material at the same, or higher level as those taught with the traditional methods.

5. CONCLUSIONS

Through the careful examination of Representation, Imagery, and Language, we have described some causes of gender bias portrayals in traditional Computer Science teaching approaches. We conclude that some existing practices are harmful to female students by decreasing their confidence, perpetuating stereotypes, and failing to proportionately include them in discourse. We offered gender equitable, alternative multidisciplinary approaches that we believe will eliminate considerable bias.

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