Increasing gender diversity in Computer Science

Are the course materials of the first year of the Computer Science Bachelor representing documented stereotypes for computer scientists?

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Abstract

The underrepresentation of women in Computer Science remains a significant issue. Stereotypes portraying Computer Science as a male-dominated field, populated by people who prefer solitude and have an obsessive interest in technology, are known to deter women from pursuing and staying in Computer Science careers. These stereotypes are often perpetuated by educational materials, further discouraging female participation. This study investigates the extent to which course materials from two introductory Computer Science courses at Delft University of Technology, 'CSE1300: Reasoning and Logic' and 'CSE1500: Web and Database Technology', reflect these documented stereotypes. By analyzing characters and scenarios depicted in textbooks, lecture slides, and videos, the research assesses whether these materials reinforce gender biases. The methodology involves a comprehensive inventory and classification of characters based on gender, social interactions, and interests. The findings suggest that both courses frequently employ stereotypical representations, especially making use of male examples, potentially contributing to the persistence of gender biases in Computer Science education. Addressing these issues by promoting diverse and inclusive examples in educational content could be a step toward increasing female retention in Computer Science programs.

1 Introduction

In Computer Science, a quickly evolving industry, women are still underrepresented. In the US, 21.2% of Computer Scientists identify as women [17]. In Europe, women make up 18.9% of the Computer Science workforce, and in the Netherlands 19.4% [9].

More gender variety in Computer Science is beneficial as a diverse team during product design ensures that a more diverse user base is considered and accommodated [3]. Furthermore, jobs in the Computer Science field are often well-paid, and if women do not work in those fields, they are not accessing a profitable market and the work market might miss out on a skilled workforce [3, 14].

One way of addressing this issue is to improve the retention of women interested in the field. Research shows that stereotypes such as Computer Science being a male domain and computer Scientists being 'geeks' that prefer being alone and are only interested in Computers deter women from the field [11]. Whilst some of these stereotypes might be established at a young age [6] they may be furthered by teaching materials in higher education [15]. Such stereotypical representation can get in the way of a diverse and inclusive classroom and could be one of the participating factors leading women to leave the field [11]. To effectively address this, it is crucial to understand how educational materials contribute to these stereotypes.

We want to explore the current standards of education materials, by analyzing the course materials of two introductory courses at TU Delft. This paper answers the following question:

To what extent do the course materials used in introductory CS courses of the TU Delft Computer Science bachelor represent documented stereotypes for computer scientists; those being a Computer scientist has to be male, prefers to be alone, and is obsessed with technology?

Specifically, we will examine the two first-year courses CSE1300 'Reasoning and Logic' and CSE1500 'Web and Database Technology'. To answer this question we analyzed the course materials, specifically mandatory reading, slides, and videos that are part of the two courses, and extracted all examples using characters or specific groups of people. We then classify characters' gender identities, whether they are described alone, and whether they represent stereotypical interests. We found a significant bias favoring male examples specifically in both courses. The group dynamics are generally biased between stereotypical and counter-stereotypical examples. Interests found in the two courses portray not only typical Computer Science stereotypes, but also stereotypical gender biases and stereotypes related to STEM as a whole.

2 Background

Stereotypes can have a negative effect on the feeling of belonging among women [13]. This can impact their perceived expectation of success in the field, possibly driving them out of the field [5].

Previous research found that a stereotypical computer scientist is described as: 'male, prefers to work alone, obsessed with technology, programming, and robotics' [3–5, 11]. Thus non-stereotypical refers to all the examples that do not fall into the stereotypical archetype, such as 'female or neutral gender representing, likes to work in groups, and enjoys sports or creative hobbies ' [5]. Whilst those stereotypes may develop in children [6] it gets further perpetuated through media [4], parents and teachers [14]. Another way they may be cultivated is through course material. This is problematic, as the inclusion of stereotypes in official course material can extend legitimacy towards possibly harmful and inaccurate stereotypes [1, p. 27]. There is an additional expectation, that a computer scientist has to be a 'genius' and already skilled when entering higher education [10]. Women tend to not see themselves fitting this mold of what a computer scientist should be and do not expect themselves to be able to succeed [4, 10]. By several interventions such as presenting diverse learning environments and incorporating a variety of interests into course materials, educational institutions can help challenge and dismantle the stereotypes that deter women from pursuing and persisting in Computer Science without discouraging men from the field [13, 15].

There is a precedence in the research of the gender disparity of course materials of STEM courses. Such as the study of popular chemistry textbooks, which found a strong bias toward men in the display of popular figures in the field, and the characters they used. Furthermore, it showed men more often depicted in occupational roles, while women were shown

in domestic activities [16]. For CS specifically, there is an investigation into the representation of gender in the illustrations of Python Programming books for children, which found more male illustrations in the majority of books it analyzed with one exception [7]. Almost half of the characters were illustrated alone, and about 15% fit the stereotypical interests. About two-thirds represent at least one stereotype, of the category male, alone or only interested in computers.

Research suggests several interventions to increase gender retention, such as changing higher education curriculum, focusing on a less competitive and more cooperative environment [10]. Other proposals include removing gendered stereotypes from course material, by replacing them with gender-equitable or gender-neutral examples, such as animals or cities to prevent representing unconscious biases in course material [15]. One approach suggests changing the focus of the examples, after finding a correlation with women preferring examples referring to people over examples referring to things [12]. This aligns with the observation that women typically have a greater interest in people and societal issues [2].

3 Methodology

To investigate the extent of stereotypical representation in first-year Computer Science Bachelor courses, we systematically analyze the presence and representation of gender stereotypes in the course materials of two introductory Computer Science courses at Delft University of Technology.

3.1 Materials

All course materials analyzed are used for self-study and fall under the VARK modalities. Specifically, they are either Visual, Auditory, Read/Write or Kinaesthetic [8]. This includes respectively, lecture slides, videos explaining course content, mandatory book chapters or exercises in the material to be solved by the student. Within these materials, all examples are analyzed on how representative they are of documented stereotypes.

This is done by inventorying all occurrences based on their stereotypical or non-stereotypical portrayal as suggested by the guide 'Promoting Gender Equality through Textbooks' [1]. Examples are counted when using characters or people to illustrate concepts. Such an example is for instance: 'Everyone likes computers'. Reoccurring examples are counted only once within the slide set of one lecture, within one chapter, and one video. Furthermore, content marked as 'bonus' or 'extra' is also excluded due to the scope of the project.

For both courses CSE1300 'Reasoning and Logic' and CSE1500 'Web and Database Technology' we look at the latest edition of the course available, namely the edition of the academic year 2023/2024.

We chose CSE1300 'Reasoning and Logic' as it is in quarter 1 and hence one of the first courses freshmen of the TU Delft Computer Science and Engineering bachelor will get in contact with. We choose CSE1500 'Web and Database Technology', which is taught in the third quarter, showing what students are shown later in their first year. They cover different departments, Models, and Data respectively, allowing us a more diverse view of how disciplines are conveyed. They are also not overly abstract, allowing the teaching staff to use plenty of examples to illustrate the material.

For CSE1300 'Reasoning and Logic' it accumulated 15 sets of Lecture slides, 4 book chapters, and 25 videos that were analyzed. For CSE1500 'Web and Database Technology', it meant analyzing 16 sets of Lecture slides, 13 book chapters, and 4 videos.

3.2 Measures and Analysis

Both the book and lecture slides were reviewed by skimming the pages for named characters or identifiable actors in an activity. The videos were inspected by playing them at double speed and at the mention of a character or an activity the video is stopped and the example is noted down. All examples were noted within a spreadsheet, where we kept track of several factors, the stereotypes, the source of the example to get back to when necessary, and additional information.

Gender

Several criteria determine the gender of a character. We look at the pronouns used to refer to them, we also look at the names they use, and if we can make conclusions about their gender by them. A name such as Tom and Mary is identified as male or female respectively, however, Sam is classified as neutral, as it is a unisex name. Furthermore, we look at their roles or descriptions and if they have gendered annotations. I.e. a wizard is identified as male, while a queen is identified as female. If this is not conclusive or a gender-neutral name is used, we assign the neutral label.

Social interactions

The social interactions of the characters identified are whether they are conversing, interacting, or active members of a group setting. If they are a member of a social group, where social interaction is expected but not explicitly described, such as 'Students', or if the example isn't conclusive such as 'Everyone eats pizza' it is labeled as in proximity of people. If a character is described as not interacting with others or to be involved in a task on their own, they are labeled as alone. Conclusively the labels we use are 'alone', 'group', and 'in the proximity of people'.

Interests

Motivated by previous research [1, 7] we used the following labels to classify activities: 'Care or Caring activities', 'Computers & Technology', 'Food & Drinks', 'Leisure, recreational and sports', 'Logic and puzzle games', 'Negative activity', 'Neutral activity', 'Occupational activity (non-CSE)', 'Outdoors & Travel', 'School or Study activity' and 'STEM'. Every character is assigned to one of these categories that best fits what they are described as doing. We label a character as representing stereotypical interests if they are classified in the 'Computers & Technology' category, i.e. if they are described as discussing or interacting with computers, robots, or video games. Additionally, we classify characters as representing stereotypical when they are originating from video games, and characters that are robots, computers, or cyborgs.

4 Findings

The findings are organized by course, detailing each individual trait as well as the identified combinations of traits.

4.1 Reasoning and Logic

The course Reasoning and Logic has used 118 examples that use characters to visualize concepts. 59 examples were found in the book, 54 in the slides, and 5 in the videos. In Table 1, the exact classifications per medium are more detailed. In graph 1 the exact numbers per category are listed.

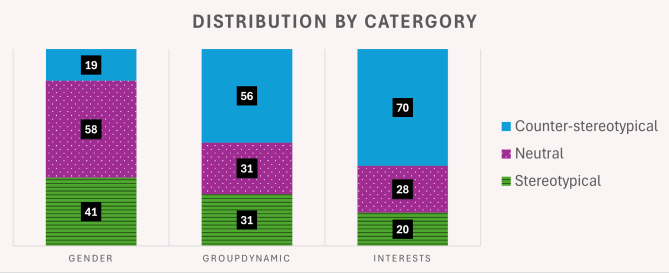

Figure 1: The classifications of all characters into stereotypical interests for the course CSE1300 'Reasoning and Logic'.

Gender

We classified 49% (n = 58) of characters as neutral. Of the gendered characters, more than twice as many are classified as male (n = 41) than female (n = 19). 31 of the characters we labeled as neutral use personal or indefinite pronouns, such as 'You' and 'Everyone'. Of the 9 characters based on real people found in the course materials, the majority (n = 7) characters were classified as male. Whilst the book and video show a bias towards neutral characters (n = 37 and n = 4) over male (n = 15 and n = 1) characters (n = 7), the slides have a bias towards male characters (n = 25) over neutral (n = 17) characters. In all cases, female characters are the least represented, with 7, 0, and 12 occurrences respectively. Additionally, the course uses intermissions in their slides to highlight researchers in and related to the field by name and picture. This occurs 9 times, of which without exception all individuals are male.

Group dynamics

The majority of characters are described in a group (n = 56). That includes 13 of the 15 characters that are inspired by game characters. Of the 31 characters depicted alone, more than half are characters referred to by personal pronouns (n = 18). The majority of these pronouns are 'You' or 'I', with only one exception where 'he' is used.

Interests

The most common interests encountered were 'Neutral' (n = 29) and 'Logic and puzzle games' (n = 21). 20 characters represent stereotypical interests, of which 15 are inspired by game characters, and the other 5 are labeled with the 'Computers & Technology' activity. 17 of these characters were found in the lecture slides, 2 in the book, and 1 in a video, as depicted in Table 1.

Combination of traits

Female characters are almost exclusively depicted in groups (n = 10) or close proximity to people (n = 8), with only one female character being explicitly described as alone. The activity female characters are most often labeled with is the 'Neutral' label (n = 8), which means there is no further information about the occupation or activity the character is engaged in. Following are the categories 'Food & Drinks' and 'Care or Caring activity', with 3 representatives each. The activity dominating for male characters are 'Logic and Puzzle games' (n = 14) followed by Neutral (n = 9).

Characters depicted in a group setting are mostly associated with the 'Logic and puzzle games category' (n = 16) and 'Care or Caring activity' (n = 13). Characters depicted alone are associated equally likely with the activity labels 'Food & Drinks', 'Neutral', and 'Logic and puzzle games' (n = 5).

The trait that occurs most often in isolation, is being male, as 25 characters are labeled as male, not described alone, and not as having stereotypical interests. The two traits most often found in combination are being male and having stereotypical interests. An example of a character depicting all three stereotypes is: "Jack owns a computer", from the course book. The graph 2 illustrates the precise distribution of the amount of traits among the characters.

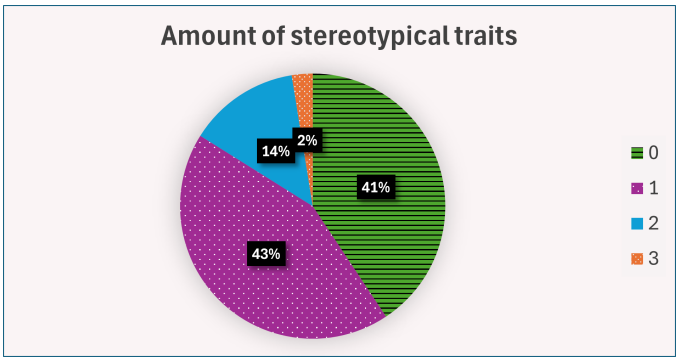

Figure 2: Percentage of characters that fit none, one, two or three stereotypical traits respectively from the course CSE1300 'Reasoning and Logic'.

4.2 Web and Database Technology

The course CSE1500 'Web and Database Technology' is taught in two parts. The first part taught in the first 5 weeks specifically covers Databases and will be referred to as Database Technology further. The second part taught in the last 5 weeks covers Web Technology and will be referred to as Web Technology. Each part has a separate course book and 8 sets of lecture slides. Database Technology uses one video, to illustrate their content, whilst Web Technology uses 3. There were 270 examples in the course CSE1500 'Web and Database Technology'. 94 of which can be found in the books. The majority, namely 89, of the character examples stem from the Database Technology book. Similarly, most of the slides' 176 characters, namely 170, are found in the first half of the course. 6 more examples can be found in the videos that are part of the course, of which 4 come from

		Gender			Groupdynamic			Interests		
Medium		**Male**	**Neutral**	**Female**	**Alone**	**In proximity**	**Group**	**Stereotypical interests**	**Non-stereotypical interests**	**Total**
Book	1 Book (∼220 pages)	15	37	7	17	18	23	2	57	59
Slides	14 slide sets	25	17	12	10	13	31	18	36	54
Video	25 videos	1	4	0	3	0	2	1	4	5

Table 1: Breakdown of the characters in the material of the course CSE1300 'Reasoning and Logic' per medium into the occurrences of gender, group dynamic, and interests respectively.

		Gender			Group dynamic			Interests		
Medium	**Amount of Material**	**Male**	**Neutral**	**Female**	**Alone**	**Neutral/In proximity**	**Group**	**Stereotypical interests**	**Non-stereotypical interests**	**Total**
Book	2 Books (∼380 pages)	39	31	24	11	54	29	23	71	94
Slides	16 slide sets	101	34	41	47	65	64	9	167	176
Video	4 videos	5	0	1	5	0	1	0	6	6

Table 2: Breakdown of the characters in the material of the course CSE1500 'Web and Database Technology' per medium into the occurrences of gender, group dynamic, and interests respectively.

Database Technology. That is only 13 examples in total that are from Web Technology. A general overview of the examples per medium can be found in Table 2. Noticeably, examples get reused in multiple lectures and hence get counted more than once. Similarly, the slides reuse examples from the book. The course includes 67 examples based on real personalities, of which 57 are from the movie or music industry.

An overview of the distribution of examples among the stereotypical traits is presented in graph 3, with a detailed breakdown as follows:

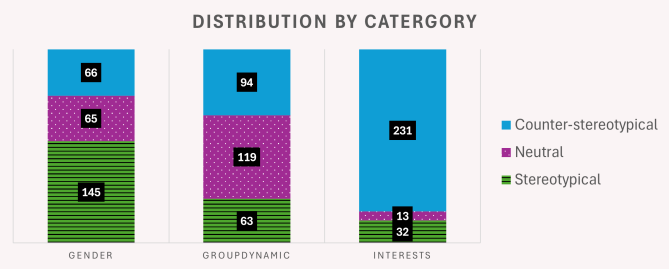

Figure 3: The classifications of all characters into stereotypical interests for the course CSE1500 'Web and Database Technology'.

Gender

We labeled more than half of the characters male (n = 145). There are approximately the same number of characters labeled as neutral (n = 65) as there are labeled as female (n = 66).

Group dynamics

The majority of the characters (n = 119) are labeled with the neutral label 'in proximity of people'. Of the 67 characters based on real people, however, only 8 examples are 'in proximity of people' the greater part (n = 41) are mentioned alone.

Interests

The representation of the 'occupational activity (non CSE)' are dominating the examples in the course CSE1500 'Web and Database Technology', as 154 of the 276 examples are labeled as such. Of the 67 characters based on real people, 60 characters fall into the 'occupational activity' category. The other 7 characters are spread among several other activities, namely 'School or Study activity', 'Food & Drinks', 'Care or Caring', 'Computers & Technology' and 'Leisure, recreational and sports'. The other common categories encountered were 'Neutral' with 36 examples, followed by 'Computers & Technology' with 29 examples and 'Care or Caring activity' with 25 examples.

Combination of traits

As shown in figure 4, the majority of examples in the course CSE1500 'Web and Database Technology' represent at least one stereotypical trait. Less than a third do not represent a single stereotype, that is 86 of the 276. A large part of the characters we labeled as female are also labeled in a group (n = 27) or in the proximity of people (n = 31). Only 8 examples that were labeled female were labeled alone. Male examples are also often described in a group (n = 51) or in the proximity of people (n = 55), however, they are also often described alone (n = 39). We labeled the majority of women (n = 39) as well as the majority of men (n = 96) with the 'Occupational activity (non-CSE)'. This goes in line, with a large amount of characters being depicted in the context of Datasets depicting real people from the movie industry and the music industry. The stereotype that occurs most often is being male (n = 101). The stereotypes that appear together most frequently as a pair are being male and being described as alone (n = 35). An example of a character that displays all three stereotypes is [lecturer name], who is male and described as an example in the process of authenticating themselves.

5 Discussion

The analysis of the course materials from introductory Computer Science courses reveals significant insights into the perpetuation of gender stereotypes within educational content.

5.1 Course analysis

In both courses, we found that most characters are described as male. More than two-thirds of CSE1500 'Web and Database Technology' show at least one commonly described stereotypical trait and for CSE1300 'Reasoning and Logic' the number is a bit under 60%. These results are comparable to the results found in research about CS Coursebooks for children by de Wit et al. [7].

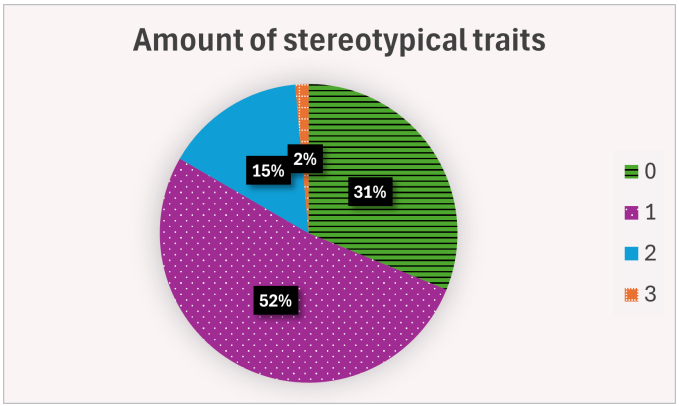

Figure 4: Percentage of characters that fit none, one, two or three stereotypical traits respectively from the course CSE1500 'Web and Database Technology'.

Many examples used in CSE1300 'Reasoning and Logic' are examples from video games, meaning the gender representation of the course material is impacted by the quality of representation in those games. Furthermore, it can be argued that such heavy inspiration from video games can reinforce a focus on video games as an integral part of being a computer scientist. Similarly, CSE1500 'Web and Database Technology' uses a lot of names based on data from the film and music industry exposing itself to similar biases as those industries. For example, we find elderly white men listed as directors while the few actresses listed tend to fall into the category of attractive young women.

Gender representation varies significantly across different categories. Women are represented in categories related to 'Food & Drinks' and 'Care or Caring activity', whereas men are typically described in occupational activities further perpetuating traditional gender roles. Even within those occupational activities, there is a gender divide; for example, the slides of CSE1500 'Web and Database Technology' speak of Joan the secretary and James from Headquarters. Together with the male directors, that stem from the biases of the movie industry, an environment gets created that paints a certain picture of women. This creates an environment that paints a certain picture of women, potentially impacting their sense of belonging and confidence in their abilities, as they stand out from the stereotypical image of what a Computer Scientist 'should' be.

Many examples of CSE1300 'Reasoning and Logic' use neutral pronouns, which consequently classify them as neutral. However, it is worth investigating how these neutral pronouns affect male and female readers' perceptions of the overall gender distribution.

The group dynamics in both courses show quite a balance between characters being depicted alone and in groups. It is important to highlight that we are counting every character, not every example of an action. Hence two characters interacting with each other will count as two characters, rather than one example. This does not significantly affect the data since instances of counted characters interacting with each other were infrequent. It is valuable to see the balanced data values, as the notion of social interactions is important to address in more meaningful ways. In fact, since more people-focused classrooms, tend to not have a negative effect on the interest of men [12], it may be beneficial to lean even more into the group interactions.

The most common interest depicted in CSE1300 'Reasoning and Logic', namely 'Logic and puzzle games' may not be directly stereotypical, however, it does support the image that a Computer Scientist has to be intelligent. Examples in that course are crafted using the lecturers as inspiration. Since the team is all male it consequently impacts the gender balance negatively. That might have contributed to the fact that no women in the field were specifically highlighted, and this space was only given to men in the lecture slides. A phenomenon not uncommon in STEM textbooks, as research in for instance chemistry textbooks has shown [16]. This lack of any mention of a female key figure, together with the male bias in examples and the general perpetuation of stereotypes of the typical Computer Scientist, may further the image of Computer Science as a male domain.

It is crucial to acknowledge that certain groups in Computer Science, including some women, are attracted to the field because of its stereotypes [13]. Therefore, the objective should not be to eliminate all stereotypes but to diversify the representations in course materials to reflect the actual diversity within the field of Computer Science.

5.2 Limitations and Responsible Research

Due to the nature of the Research Project, the annotation that is usually done by two or more researchers is done by one researcher. This may lead to biases. For instance, the prevalence of human error may increase due to the quantity of the material. One may mislabel or simply miss an instance of a character and hence slightly skew the data. Furthermore, there may be a selection bias in the choice of courses, which has been covered in this paper. Since the scope of the Research project only allows us to look at two courses, the results may not be representative of all of TU Delft or the Computer Science field, especially as both courses have an all-male teaching team. However, as our results align with previous research, we expect them to be representative. The researcher working on this project identifies as a female, which might come with biases when categorizing and interpreting the data. To ensure transparency we keep a spreadsheet of the examples, their labels, and their location in the data, which will be shared alongside the paper[1].

6 Conclusions and Future Work

We aimed to answer the following question

To what extent do the course materials used in introductory CS courses of the TU Delft Computer Science bachelors represent documented stereotypes for computer scientists, that is a Computer scientist has to be male, prefers to be alone, and is obsessed with technology?

We achieved this by taking inventory of all examples in the course book, slides, and videos of two first-year courses

[1]The spreadsheet can be found here: https://1drv.ms/x/s!AhSb9WrbeqXmhuh1LDygs04m1AF3Fw?e=fiAD8e

CSE1300 'Reasoning and Logic' and CSE1500 'Web and Database Technology'.

We found that the two introductory courses selected are quite representative of the stereotypes documented in the literature. Overall there is a bias towards male characters in both courses, which may be impacting the feeling of belonging among women negatively. Both courses have a relatively balanced representation of single and grouped group dynamics. Both courses have between 12% and 17% of a stereotypical interest representation. The most common trait occurring in isolation in both courses is being male. The findings of this study highlight the importance of ongoing efforts to critically evaluate and improve educational materials to ensure they support, rather than hinder the participation of women in computer science.

We recommend increasing the depth and span of the research, as well as researching ways to offset biases and their effects. To go more in-depth, we recommend looking at the type of representation. This paper classifies whether the characters apply to the stereotypical depiction of a Computer Scientist, without further analyzing the power dynamics of the characters or whether they are described in a positive or negative context. It would be interesting to further explore how other examples are depicted.

To increase the span of the research an intuitive change is to analyze more courses, perhaps also from different universities. Additionally, examples could be analyzed that do not involve characters. There is plenty of use of illustration or descriptions that do not involve characters but can still portray stereotypes. It might be insightful to look at trends in courses over time and possible differences between teaching teams that do or do not include women.

One could also consider further measures of inclusively, for instance, non-binary gender representations, disability, people of color, and non-hetero-normative characters, and explore them in the context of intersectionality. Whilst we expect a mindful approach when creating examples, that aim for a more equitable and unbiased representation of stereotypical and counter-stereotypical characters it might be interesting to research how to offset historical biases while representing and teaching, and how to highlight more diverse researchers in the field.

Lastly, it would be interesting to research the perceived effects of the stereotypical representations and possible interventions on current Computer Science students, especially since first-year students taking the introductory courses have an already established interest in the course matter.

We aim for our work to be a step towards understanding the biases present in the industry, and we hope it will contribute to improving Computer Science education by removing barriers that women and diverse groups may face in entering and staying in the field.

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