Increasing gender diversity in Computer Science

A research on gender inclusivity in materials provided during the matching and selection process

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Abstract

This study evaluates the gender inclusivity of selection materials for computer science programs at TU Delft, TU Eindhoven, and Vrije Universiteit Amsterdam. By scrutinizing heuristics analysis, we determine the supportiveness and potential biases of these materials. While all three universities employ gender-neutral language and second-person pronouns, TU Delft stands out for its balanced gender representation in imagery and extensive preparatory resources using a normalized scoring system. In contrast, TU Eindhoven and Vrije Universiteit Amsterdam show greater gender imbalance in visuals and rely on absolute scores, potentially introducing bias. Future research should include non-binary gender representations and extend to more European universities to develop a comprehensive understanding of gender inclusivity in academic selection processes.

1 Introduction

Gender inclusivity in Computer Science (CS) remains a pressing challenge globally, with women consistently underrepresented in this field. In 2021, women made up only 21.2% of computer scientists in the United States [12] and 19.1% of Information and Communications Technology (ICT) specialists across Europe [5]. This disparity is not only problematic for gender equality but also poses a significant threat to economic development. With the high number of unfilled IT vacancies in Europe and the rapid digitization of society, increasing the participation of women in CS is essential [8]. Filling this gap could enhance economic growth, reduce biases in technological products, and provide greater access to well-compensated, in-demand careers.

Despite initiatives to encourage more women to pursue careers in CS, many continue to opt out due to low self-efficacy [1], perceived lack of interest, stereotypes, and a sense of not fitting into the field [10]. Universities have a crucial role in influencing the perceptions and decisions of potential students. Thus, it is essential to examine the selection materials and procedures used by educational institutions to attract a diverse student body.

This study will analyze the matching and selection procedures at multiple universities in the Netherlands to determine the inclusivity of their materials and methods for women. It will investigate two key sub-research questions to shed light on these practices:

- **RQ1: How gender inclusive are the materials created by Dutch universities for matching and selection?** The study will scrutinize the wording, imagery, and pronoun use in selection materials to determine whether these elements are supportive and welcoming to all genders or implicitly biased toward one.
- **RQ2: How do the materials provided by Dutch universities ensure fairness across all genders?** By assessing the opportunities, expectations, and career outcomes presented, this research will explore whether the content of these materials establishes an equitable basis for both genders.

This comprehensive investigation will generate practical recommendations for improving gender inclusivity in CS programs. By identifying and promoting best practices, universities can better tailor their selection processes to encourage more women to pursue CS studies. In the long run, this will contribute to a more diverse and representative tech workforce and promote equitable opportunities in one of the fastest-growing and most crucial sectors of the global economy.

2 Background

Gender inequality in computer science is a pervasive issue with deep-rooted cultural and systemic barriers that discourage women from entering and persisting in the field. Despite some progress, women remain significantly underrepresented in computer science and related disciplines, which has broad implications for innovation, economic growth, and social equity. Some of the current issues of gender inequality in computer science are as follows:

Cultural Norms and Stereotypes: Cultural norms and stereotypes continue to discourage girls from pursuing computer science from an early age. These stereotypes are often reinforced by parents, educators, and media, portraying computer science as a male-dominated field. Consequently, fewer girls develop an interest in computer science during their formative years, leading to lower enrollment rates in higher education and professional settings [2; 10]. Studies indicate that girls often perceive computer science as less welcoming due to its male-dominated image, which affects their decision to pursue this field [9].

Lack of Role Models: The scarcity of visible female role models in computer science further amplify the issue. When young girls do not see women in prominent roles within the field, they are less likely to envision themselves in similar positions. This lack of representation is evident in both academia and industry, where women hold fewer senior positions and receive less recognition [4]. The absence of role models can lead to a lack of inspiration and support for young women considering careers in computer science [6].

Systemic Barriers: Women face numerous systemic barriers, including gender bias in hiring and promotion, less access to funding and resources, and a work culture that can be unwelcoming or even hostile to women. For example, women-led startups receive only a small fraction of venture capital, and women in academia often receive less grant funding despite being equally productive as men [7; 11]. These barriers contribute to a lower retention rate of women in the field, perpetuating the cycle of under-representation.

The current issues of gender inequality in computer science highlight the necessity for inclusive university selection materials. These materials can serve as a powerful tool to combat these entrenched problems. By intentionally designing university selection materials to be inclusive, educational institutions can directly address and counteract

the negative impacts of these issues. For instance, showcasing successful female computer scientists in university brochures and websites can help dismantle stereotypes and provide young women with role models they can aspire to. Furthermore, inclusive materials that emphasize support structures such as mentorship programs and women-in-tech clubs can create a welcoming environment that encourages more female students to pursue computer science. Increasing gender equality within computer science may bring the following benefits:

Encouraging Early Interest: By showcasing diverse role models and success stories of women in computer science, university materials can inspire young girls to pursue this field. Highlighting the achievements of female computer scientists can help break down stereotypes and show that women can and do succeed in this domain. This can counteract cultural norms and provide early exposure to positive role models, fostering interest and engagement from a young age [9].

Creating a Supportive Environment: Inclusive materials that emphasize a supportive and welcoming environment for women can help attract more female students. This includes information on mentorship programs, women in STEM clubs, and other resources aimed at supporting women throughout their education and into their careers. A supportive learning environment can help mitigate the negative impacts of systemic barriers and create a sense of belonging and community for female students [3].

Promoting Economic and Social Benefits: Gender diversity in computer science is not only a matter of equity but also a driver of innovation and economic growth. Diverse teams bring a wider range of perspectives, which can lead to more innovative solutions. Moreover, increasing the participation of women in technology can help address the skills shortage and boost economic productivity. For example, the European Commission estimates that greater gender equality in digital sectors could significantly boost the EU's GDP [7].

As a result, gender-inclusive university selection materials are essential for fostering a more equitable and diverse computer science field. By addressing cultural stereotypes, providing role models, and creating supportive environments, these materials can help attract and retain more women in computer science, ultimately benefiting both the industry and society as a whole.

3 Methodology

To evaluate the gender inclusivity of university selection materials, we employed a heuristic analysis approach for both research questions. This method involved using predefined heuristics to systematically assess the content and presentation of materials available during the matching and selection processes at universities.

3.1 Heuristics Analysis

We examined the following aspects from the application materials:

Language and Imagery: We analyzed the language, especially the pronouns and wording, used in the materials to ensure it is inclusive and free of gender bias. The analysis included counting instances of gender-specific pronouns and comparing them to the use of gender-neutral pronouns. We also assessed the tone and inclusivity of the wording by examining phrases and sentences for implicit biases. Imagery was reviewed to ensure a balanced representation of genders in various academic and extracurricular activities. This involved categorizing individuals depicted by gender and role (e.g., student, faculty, leader) and calculating the percentage of male and female representation.

Representation of Female Role Models: We checked for the presence of female role models in the selection materials, such as brochures, websites, and promotional videos. The prominence of these role models was assessed by noting their visibility and the context in which they were presented (e.g., leading projects, participating in interviews). Additionally, we evaluated the diversity among the female role models to ensure a broad representation of roles within the computer science department.

Equal Opportunity Based on Background Education: We analyzed whether the university selection materials indicated an openness to students from diverse educational backgrounds. This included reviewing the materials for mentions of support programs, preparatory courses, or bridging programs aimed at students from non-traditional backgrounds. We noted whether these programs were highlighted and how accessible they appeared to prospective students. We also assessed the inclusivity of the admissions criteria by looking for explicit statements about valuing diverse educational backgrounds.

Expectation Setting: We analyzed how the materials set expectations for prospective students, looking for language that might suggest different expectations based on gender, such as stereotypes about who is more suited for technical or leadership roles. This involved examining phrases related to technical skills, leadership potential, and career ambitions. Additionally, we assessed whether the materials encouraged all students, regardless of gender, to pursue ambitious career goals and leadership positions in the field. This was done by noting the presence of supportive language and resources aimed at fostering ambition and leadership among all students.

3.2 Data Collection

The data collection process involved three universities in the Netherlands: Technische Universiteit Delft, Technische Universiteit Eindhoven, and Vrije Universiteit Amsterdam, all of which offer computer science bachelor programs in English. We gathered all available selection materials from these universities, including printed brochures, websites, and promotional videos. This comprehensive collection of materials served as the basis for our heuristic analysis, allowing us to systematically evaluate the representation, language, and imagery highlighted in the selection processes of these institutions.

We recorded the data in a detailed spreadsheet. The spreadsheet includes columns for each heuristic and entries for each piece of selection material analyzed. Each entry was categorized based on specific criteria related to the heuristic, ensuring consistency and objectivity in our evaluation.

4 Results

This section presents the findings from our analysis of the selection materials of TU Delft, TU Eindhoven, and Vrije Universiteit Amsterdam, focusing on language and imagery, representation of female role models, equal opportunity based on background education, and expectation setting.

4.1 Language and Imagery

Our analysis of the use of pronouns and the choice of words in the selection materials revealed that all three universities consistently used second-person pronouns (”you” and ”your”), as can been seen in Table 1. This approach avoids third-person pronouns (such as ”he/him” or ”she/her”), which can carry implicit gender assumptions. The inclusive use of second-person pronouns helps to create a neutral and welcoming environment. In addition to pronouns, the choice of wording was notably neutral across all three universities. Terms like ”students” or ”applicants” were consistently used, avoiding binary gender references and remaining inclusive of non-binary individuals.

	Male	Female	Neutral
TU Delft	0	0	263
TU Eindhoven	0	0	120
VU Amsterdam	0	0	234

Table 1: The number of pronoun of each gender used in the material

The imagery used in the selection materials showed a noticeable difference in gender balance. As seen in Figure 1, TU Delft offered the most balanced representation of male and female students, while TU Eindhoven and Vrije Universiteit Amsterdam showed a greater discrepancy in gender representation, respectively 33.3% and 36.3% .

For instance, TU Delft’s materials featured a nearly equal number of male and female students engaged in various activities, as seen in Figure 2. In contrast, TU Eindhoven and Vrije Universiteit Amsterdam had materials not only where male students were more prominently featured, but also often showed male students participating in activities, such as group discussions, presenting research findings, or attending lectures, with female students present less frequently and in less central roles, such as Figure 3.

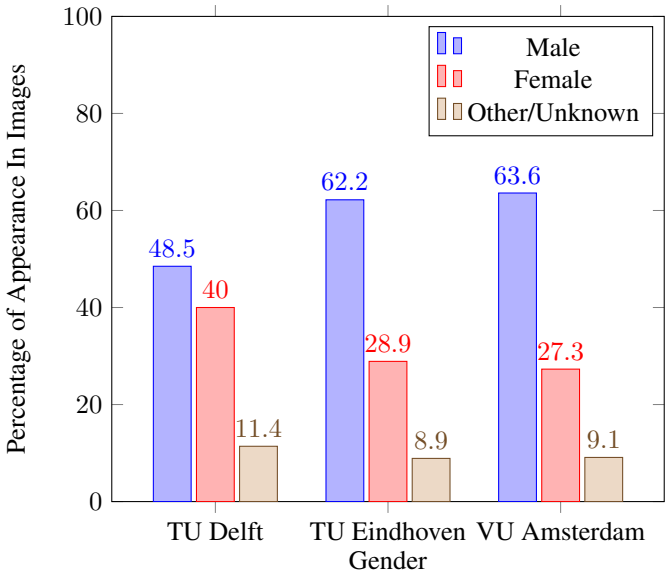


Figure 1: Percentage of appearance of each gender in all images available

Figure 2: Image on the cover of TU Delft brochure where male and female students are studying together

Figure 3: Image in TU Eindhoven brochure where only male students are attending lecture

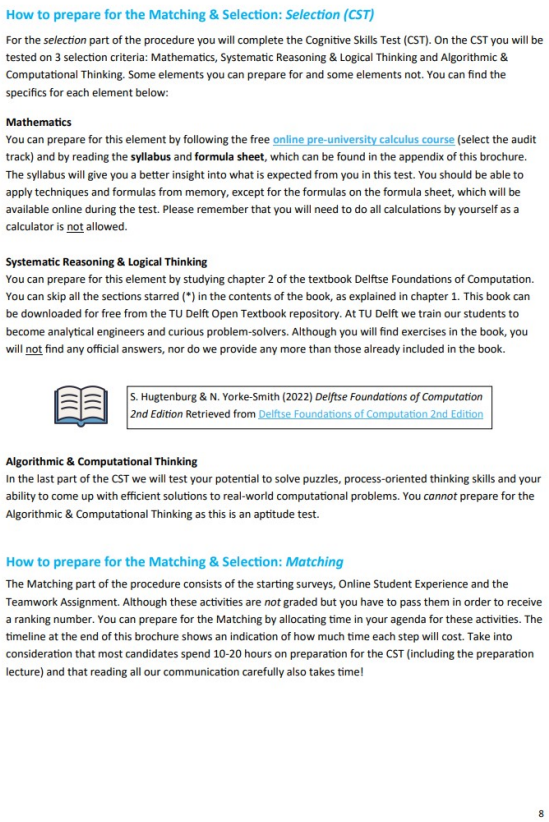
4.2 Representation of Female Role Models

Evaluating the diversity and prominence of female role models within the computer science departments of these universities reveals significant differences. TU Delft ensures that female role models are not only present but also prominently featured in leading roles. This includes highlighting female professors leading research teams, female students excelling in competitions, and female alumni holding influential positions in the tech industry.

In contrast, TU Eindhoven and Vrije Universiteit Amsterdam, while showcasing female role models, tend to feature them in less central roles. The emphasis is often on collective achievements rather than individual leadership, which may not fully highlight the contributions of women in their programs. This difference in representation can impact how prospective female students perceive their potential for success and leadership in these institutions.

4.3 Equal Opportunity Based on Background Education

Our analysis focused on how the universities address equal opportunity based on background education, particularly in their matching and selection processes. TU Delft offers the most equitable platform by providing extensive preparatory resources, such as textbooks and MOOCs, for applicants to prepare for selection exams, as seen in Figure 4. Additionally, TU Delft uses a normalized scoring system (z-score) for the final ranking, which mitigates the effects of different educational backgrounds.



How to prepare for the Matching & Selection: *Selection (CST)*

For the *selection* part of the procedure you will complete the Cognitive Skills Test (CST). On the CST you will be tested on 3 selection criteria: Mathematics, Systematic Reasoning & Logical Thinking and Algorithmic & Computational Thinking. Some elements you can prepare for and some elements not. You can find the specifics for each element below:

Mathematics

You can prepare for this element by following the free online pre-university calculus course (select the audit track) and by reading the **syllabus** and **formula sheet**, which can be found in the appendix of this brochure. The syllabus will give you a better insight into what is expected from you in this test. You should be able to apply techniques and formulas from memory, except for the formulas on the formula sheet, which will be available online during the test. Please remember that you will need to do all calculations by yourself as a calculator is not allowed.

Systematic Reasoning & Logical Thinking

You can prepare for this element by studying chapter 2 of the textbook Delftse Foundations of Computation. You can skip all the sections starred (*) in the contents of the book, as explained in chapter 1. This book can be downloaded for free from the TU Delft Open Textbook repository. At TU Delft we train our students to become analytical engineers and curious problem-solvers. Although you will find exercises in the book, you will not find any official answers, nor do we provide any more than those already included in the book.

S. Hugtenburg & N. Yorke-Smith (2022) *Delftse Foundations of Computation 2nd Edition* Retrieved from Delftse Foundations of Computation 2nd Edition

Algorithmic & Computational Thinking

In the last part of the CST we will test your potential to solve puzzles, process-oriented thinking skills and your ability to come up with efficient solutions to real-world computational problems. You *cannot* prepare for the Algorithmic & Computational Thinking as this is an aptitude test.

How to prepare for the Matching & Selection: *Matching*

The Matching part of the procedure consists of the starting surveys, Online Student Experience and the Teamwork Assignment. Although these activities are *not* graded but you have to pass them in order to receive a ranking number. You can prepare for the Matching by allocating time in your agenda for these activities. The timeline at the end of this brochure shows an indication of how much time each step will cost. Take into consideration that most candidates spend 10-20 hours on preparation for the CST (including the preparation lecture) and that reading all our communication carefully also takes time!

8

Figure 4: Page of TU Delft brochure mentioning how to prepare

In contrast, both TU Eindhoven and Vrije Universiteit Amsterdam offer little to no information on how applicants can prepare for selection exams. This lack of preparatory resources may create an advantage for students from certain educational backgrounds. Additionally, both universities use an absolute score where the final GPA of the high school bachelor is included, which can introduce bias towards students from different schooling systems.

4.4 Expectation Setting

Analyzing how the selection materials set expectations for prospective students is another vital aspect of our study. We specifically looked for language that might suggest different expectations based on gender, such as stereotypes about who is more suited for technical or leadership roles. We also assessed whether the materials encourage all students, regardless of gender, to pursue ambitious career goals and leadership positions in the field.

All three universities—TU Delft, TU Eindhoven, and Vrije Universiteit Amsterdam—are clear in setting high expectations for all prospective students without any gender bias. The materials uniformly emphasize the potential for all students to achieve success in their academic and professional careers. For example, phrases like ”After completing your bachelor degree, you can launch your career immediately: computer scientists are in high demand.” and ”If you come from TU Delft, you can do more than just programming.” are used without reference to gender.

5 Discussion

This section discusses the findings from our results, answering the research questions on gender inclusivity and fairness in the selection materials of Dutch universities.

5.1 RQ1: How gender inclusive are the materials created by Dutch universities for matching and selection?

The analysis indicates that the selection materials of TU Delft, TU Eindhoven, and Vrije Universiteit Amsterdam exhibit a strong commitment to gender inclusivity through the use of pronouns and wording. All three universities exclusively use second-person pronouns (”you” and ”your”), avoiding first-person and third-person pronouns, which can carry implicit gender assumptions. This consistent use of second-person pronouns helps create an inclusive and neutral language environment, effectively eliminating many potential gender biases.

The choice of neutral wording throughout the selection materials further supports gender inclusivity. Examples such as ”students” or ”applicants” avoid gender-specific language, ensuring that all prospective students feel addressed and included. This approach not only simplifies communication but also aligns with best practices in promoting gender neutrality in educational resources, making the materials supportive and welcoming to all genders.

However, the imagery used in the selection materials reveals differences in gender representation. TU Delft provides a balanced representation of male and female students, featuring nearly equal numbers of each gender engaged in various academic and extracurricular activities. This balanced imagery helps create an inclusive and diverse academic environment where both male and female students are equally valued and visible.

In contrast, TU Eindhoven and Vrije Universiteit Amsterdam show a greater discrepancy in gender representation. Male students are more prominently featured in key roles, while female students appear less frequently and often in less central roles. This imbalance can subtly convey that male students are more active or prominent in the academic community, potentially discouraging female applicants from feeling fully included or represented.

5.2 RQ2: How do the materials provided by Dutch universities ensure fairness across all genders?

The analysis of opportunities, expectations, and career outcomes presented in the selection materials highlights significant differences in how the universities address equal opportunity based on background education. TU Delft offers the most equitable platform by providing extensive preparatory resources, such as textbooks and MOOCs, for applicants to prepare for the selection exams. Additionally, TU Delft uses a normalized scoring system (z-score) to derive the final ranking, which mitigates the effects of different educational backgrounds.

In contrast, both TU Eindhoven and Vrije Universiteit Amsterdam offer little to no information on how applicants can prepare for the selection exams. This lack of preparatory resources may create an advantage for students from certain educational backgrounds who might already be familiar with the exam content. Furthermore, both universities use an absolute score where the final GPA of the high school bachelor is included, which can introduce bias towards students from different schooling systems. This approach may perpetuate existing stereotypes and biases present during high school, potentially affecting gender equality as well.

All three universities set high expectations for all prospective students without any gender bias. The materials uniformly emphasize the potential for all students to achieve success in their academic and professional careers. Phrases like ”students are encouraged to pursue their passions in cutting-edge research” and ”our graduates become leaders in technology and innovation” are commonly used without reference to gender.

By setting these inclusive expectations, the universities help break down stereotypes that might suggest certain genders are more suited for particular roles. This approach not only promotes gender equality but also fosters an environment where all students feel empowered to pursue their ambitions, regardless of gender.

6 Responsible Research

In conducting this research on gender inclusivity in university selection materials, it is crucial to address several ethical aspects to ensure the integrity and responsibility of the study. Ethical research practices are foundational to producing valid, reliable, and socially beneficial outcomes, especially when addressing sensitive issues such as gender equality. Following are some important information that needed to be taken into consideration.

Avoidance of Harm: The analysis and dissemination of this research should aim to avoid any harm to the institutions or individuals involved. Critiques of the selection materials should be constructive, focusing on areas for improvement rather than unduly negative criticism. This approach helps foster a positive dialogue around gender inclusivity and encourages institutions to adopt more inclusive practices. By framing feedback constructively, the research can serve as a catalyst for positive change, promoting practices that support and encourage female participation in computer science.

Reproducible and Detailed Methodology: The research methodology will be documented in detail, including the selection of universities, the specific heuristics used for analysis, and the criteria for evaluating the selection materials. By providing a clear and comprehensive description of the methods, other researchers can replicate the study in different contexts or with different institutions. This detailed documentation ensuring that every aspect of the research can be accurately reproduced.

Consistent Application of Heuristics: To further ensure reproducibility, the heuristics will be applied consistently across all selected universities. This involves using the same criteria and analytical framework for each set of materials, minimizing subjective bias and enhancing the reliability of the findings. Detailed records of the analysis process will be maintained to provide transparency and allow for verification. By standardizing the application of heuristics, the study ensures that the results are comparable and reliable, providing a robust basis for further research.

This research is committed to possess ethical standards and ensuring the reproducibility of its methods. By reflecting on and addressing the ethical aspects of the study and meticulously documenting the research process, we aim to contribute to a more inclusive and equitable academic environment in computer science.

7 Limitations

This study provides valuable insights into the gender inclusivity of selection materials from three Dutch universities; however, several limitations should be considered.

Firstly, the study focused on TU Delft, TU Eindhoven, and Vrije Universiteit Amsterdam. While these universities offer English-taught computer science programs to international students, they represent only a subset of the broader landscape of Dutch higher education institutions. Therefore, the findings might not be representative of all Dutch universities. Other institutions may have different practices and policies that could affect gender inclusivity in their selection materials.

Secondly, the analysis was carried out solely by the researcher, introducing a degree of subjectivity in the assessment of the materials. While predefined heuristics were used to maintain consistency, the lack of verification from multiple reviewers means the analysis might not fully capture all nuances or potential biases. Future studies should consider involving multiple analysts to cross-verify findings and reduce individual bias.

Additionally, the heuristics used in this study were designed to capture key aspects of gender inclusivity, such

as language, imagery, representation of female role models, and equal opportunity based on background education. However, these heuristics might not cover all possible dimensions of gender bias. Other factors, such as cultural biases, intersectionality (considering other aspects like race, socioeconomic status, etc.), and non-binary gender representation, were not fully explored. Expanding the heuristics to include these dimensions could provide a more comprehensive understanding of inclusivity.

Lastly, university materials and policies can change over time. The study captured a snapshot of the selection materials as they were at the time of analysis. Future updates to the materials might address some of the issues identified or introduce new ones. Regular, longitudinal studies are necessary to monitor these changes and assess their impact on gender inclusivity.

8 Conclusions and Future Work

Overall, the matching and selection materials from TU Delft, TU Eindhoven, and Vrije Universiteit Amsterdam demonstrate varying levels of gender inclusivity. TU Delft leads in promoting a balanced and inclusive environment through its imagery, representation of female role models, and equitable selection processes. While the use of inclusive wording and pronouns is consistent across all three universities, improvements are needed in visual representation and support for applicants from diverse educational backgrounds at TU Eindhoven and Vrije Universiteit Amsterdam. Ensuring all aspects of the selection materials support gender diversity and inclusivity is crucial for fostering a diverse and welcoming environment in computer science programs.

This study specifically examined the representation of female students in the matching and selection materials of Dutch universities. Future research could expand this analysis to include non-binary gender representations, providing a more comprehensive understanding of gender inclusivity. Additionally, extending the study to include more universities across Europe would offer broader insights into how different institutions approach gender inclusivity in their selection processes. This expanded scope would help identify best practices and areas for improvement, contributing to the development of more inclusive academic environments worldwide.

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