Gender Gap in IT and Computer Science: Nip the Evil in the Bud

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Abstract: Science, Technology, Engineering, and Mathematics (STEM) describes a broad interdisciplinary approach to education and careers that enclose these four fields. STEM fields are highly influential in driving innovation, technological advancements, and economic growth. For decades, women have faced judgment when pursuing careers beyond their household duties. As the world continues to evolve, it is becoming increasingly evident that greater female participation is essential in addressing a better future. However, in the era of the internet and artificial intelligence, the biggest gender gap can be seen in the fields of Information Technology (IT) and Computer Science. This article aims to closely examine the representation of women in STEM areas, in general, and IT and Computer Science, in particular, while examining the underlying causes of the pronounced gender gap. It will also investigate the factors contributing to this separation to provide strategies and actions that can successfully help close the gap.

Keywords: Female Students, IT, STEM, Gender Equality, Gender Gap

1. Introduction

The need for Information Technology (IT) and Computing Science education is recognized as being of central relevance for meeting current social and economic challenges, as well as for developing a scientifically, mathematically, and technologically literate citizenry (Pereira et al., 2024). In many countries, however, there are gender differences in the participation and achievement of women in IT and Science, Technology, Engineering, and Mathematics (STEM) education and careers (World Economic Forum, 2024).

In the past, men were primarily responsible for earning income for the household, while women took care of domestic duties. As time progressed, women began to enter the workforce as well. The labour market has evolved over the years; however, certain areas have not reached gender equality. STEM fields, particularly IT and Computer Science, are significantly impacted. Many reasons may explain why women are depreciated in this area, some of which come from a long time ago. For example, the belief that women are more emotional and hysterical, that they should behave in a nurturing manner, and the assumption that they lack logic and analytic skills that only men possess (Acker, 1990; Diekman et al., 2010; Wang & Degol, 2017). Most of these assumptions are not based on scientific evidence (Meyers-Levy & Loken, 2015), representing only thoughts influenced by society, induced by sociocultural factors. Sociocultural factors are based only on social and cultural influences that can shape individuals' beliefs, values, behaviours, and even opportunities within a given society. These factors significantly influence various aspects of human life, including education, career choices, and participation in fields like STEM (Pereira et al., 2024). Regarding the underrepresentation of women in STEM, social-cultural factors can contribute to the gender gap. The world is evolving and changing in its efforts to address the gender gap. However, this progress is not enough, there is much more work to be done. Based on literature and some case studies in developing countries and in the Portuguese case of the university of Aveiro, this paper aims to identify some of the causes of the gender gap in IT and Computer Science and explore ways to decrease it.

This paper is organized as follows. After this introduction, section 2 presents the literature review of female IT students, centred on the framework of female IT and STEM students, the gender differences, the importance of understanding stereotypes in IT; and the most common issues in STEM education and gender differences in IT. Section 3 provides statistical evidence supporting these discussions. Section 4 analyses the causes and solutions for the gender differences. Finally, Section 5 summarizes the conclusions and offers strategies for implementation to close the gender gap.

2. Literature Review

The framework to support female IT and STEM students' research can be based on several models. Yates and Plagnol (2022) state the model of Cheryan et al. (2017), which is based on three elements, that combine fields unappealing for women: i) the masculine culture, ii) the lack of early exposure for women, and iii) women's lack

of belief in their ability to succeed. However, this model does not aim to offer a comprehensive overview of the experiences of women in these fields, and there are some aspects of women's experiences in STEM that are not considered in the framework. According to Ayre et al. (2023) the framework does not cover the experiences of some sexism, microaggressions, and sexual harassment that women in STEM fields report as well not refer to women's struggle to see how to best manage their careers within STEM fields (Yates & Skinner, 2021).

2.1 Women in STEM

The workforce in the United States of America (USA) is equal when considering the number of male and female people, however, when it comes to STEM positions, women hold less than 30% (Glass, et al., 2023; Martinez & Christnacht, 2021). Women only hold 12% of architectural and engineering jobs, while in the field of human resources, 78% of the positions belong to women. Table 1 shows the percentage of women with bachelor's degrees in STEM fields based on research conducted.

Table 1: Representative of Women in bachelor's degrees in STEM fields in the USA

STEM Field	Percentage of women representatives in a certain field	Percentage of women at a graduate level
Biological/Biomedical sciences	59%	54%
Mathematics and statistics	43%	29%
Physical and technological sciences	38%	34%
Engineering	19%	23%
Computer and Informatic Sciences	18%	19%

In Table 1, the most populated fields by women are biological and biomedical sciences. Wang and Degol (2017) cite some studies like Ceci and Williams (2011), Diekman et al. (2010, 2011), Freund et al (2012), Su et al (2029) and Tai et al (2006) that found reasons to explain the different percentages on STEM fields to women often choose degrees that contribute positively to society, driven by a desire to help others. Merayo and Ayuso (2023) found a correlation between girls choosing health and education fields to help others, while boys are more likely to choose fields like engineering or computer science because they prioritize financial gains. Additionally, girls tend to view themselves as less intelligent and lack the confidence they believe is necessary to pursue a STEM education.

Some analysts suggest that while many women have an interest in mathematics, they tend to pursue challenging non-STEM careers (Wang & Degol, 2017; Stoet and Geary, 2018), such as healthcare management or finance, instead of more complex STEM fields like engineering or computer science. Additionally, women generally prefer career paths that involve less risk. Fields such as engineering and computer science often require a willingness to experiment and accept failure, which can be more challenging for women according to research by Kovaleva et al. (2023) and Spieler et al. (2020). This tendency is sometimes referred to as female perfectionism, which is an expectation placed on girls from an early age by society. Stereotypes are intrusive thoughts established by society that can affect a person's beliefs and change the way they see the world or behave (Master et al, 2016; Spieleret al., 2020; Vichayapai et al, 2011). Researchers have found that society implies the stereotype that men are better at STEM subjects, however, studies have been made and this idea has been refuted. Women tend to have better grades in math and science in elementary and high school (Glass et al, 2023). Hill et al. (2010) concluded that a "smarter sex" does not exist, rather it is all a society's imposition that exists in different cognitive strengths. For instance, is true that when it comes to spatial orientation and visualization, boys tend to have better ability in it, while girls generally outperform boys in verbal skills, such as writing and reading, as well as in memory and perceptual speed. It is important to recognize that both genders exhibit strengths in different areas, but it's essential to recognize that these skills can be trained and enhanced through hard work.

The presence of stereotypes during childhood significantly contributes to the gap (Pereira, et al., 2019). One of these examples of gender stereotypes is the assumption that women are family caretakers and men are the breadwinners (Kovaleva et. al, 2023; Margolis et al., 2000). Society implies that women are meant to prioritize family goals, rather than their career success. Normally STEM jobs are seen as more hardworking and time-consuming, and having kids is also a full-time job that can decrease women's productivity. Hill et al. (2010)

illustrate that a woman is more likely to be hired and promoted if she is single and that married women are at a disadvantage to married men. Recent research suggests that individuals tend to be more productive when their schedules are packed with various tasks, as it fosters a mindset focused on optimizing time utilization.

Kovaleva et. al (2023) investigated the reasons behind the lack of women in entrepreneurship. The factors contributing to this underrepresentation are similar to those affecting women's participation in STEM fields. Their study identifies several reasons why women are not more eminent in entrepreneurship. Entrepreneurship is frequently associated with men, particularly in the tech industry, where the term 'tech-bros' has emerged to describe a specific demographic of male entrepreneurs. Women are way less represented than men in this field and research concluded that during pitches by company leaders, 67% of questions directed to men were about business development and 66% of questions directed to women were about preventing failures in the company. This shows that women are not trusted by their own company and are not seen with confidence by others. So, this lack of confidence in themselves may influence their way of living, making life choices, and also how others see them.

Christensen (2023) explored the possible causes of the misrepresentation of women in STEM, and he finds a link between societal wealth and the gendered confidence gap in computing, which is illustrated in a bivariate regression slope graph to illustrate the relationship between gender gap in self-assessed tech ability and societal affluence. The data supports the affluence paradox, suggesting that as societies become wealthier, gender inequalities in self-reported technological aptitude increase.

2.2 Gender Stereotypes

From birth, girls are typically associated with pink and boys with blue. Girls are expected to play with dolls, whereas boys with cars. Boys are often supported in participating in adventurous activities, such as climbing trees, whereas girls may be more frequently nudged toward quieter play, such as interacting with dolls like Barbies in serene environments. While society continues to evolve and people's mentalities change, this thought still exists in today's world. For example, in Germany, a study conducted on students aged 12 to 14 in a robotic program concluded that boys had more positive thoughts regarding robotics than girls. Van Wassenaer et al. (2023) concluded that boys have a better attitude regarding STEM and are, in general, more confident in the technical ability of engineering and building new things. On another note, researchers highlighted the importance of providing incentives from an early age, especially for girls, to change their perceptions of their capabilities.

STEM fields have numerous requirements, particularly in math. Parents and family play a crucial role in shaping their children's perceptions by communicating their gender-biased beliefs (Dickhäuser & Meyer, 2006 Pereira et al, 2024, Spieler et al.,2020). Jacobs and Eccles (1992) showed that parents tend to think that their sons are more likely to succeed in math than their daughters. Overall, according to Voyer and Voyer (2014), society tends to look at boys with more math abilities than girls, yet it was revealed that both genders have equality in math ability. Therefore, this is not one of the reasons that can explain the gender gap in STEM, since for this field good grades are necessary to get in (and to do it). Girls have a higher probability of having high math and verbal skills unlike boys (Wang & Degol, 2017), who usually are not keen on verbal skills. This can be explained by the way they are educated, since during the kid's childhood, mothers are seen by girls to be more supportive and easier to talk to, on opposite with boys, and parents appreciate quality time with their daughters by reading or storytelling.

These findings can explain why girls have more verbal ability than boys, a really important soft skill when going to the job market and deciding their path. Since they are keen on both strands, they tend to be inclined towards non-math careers, but why?

When growing up, according to Gabay-Egozi et al. (2015), Giannakosat al. (2017), and Vichayapai et al, 2011), children, especially teenagers, need someone to look up to, role models, and there is a big lack of female STEM role models. Kids can get inspired by what they learn in school, by their toys, and by TV shows. It is important to introduce at a young age the concept that gender does not define who they can be one day in terms of job choice (Young et al., 2013).

Nowadays, are coming up with TV shows for children with more girls in power. Exemplifying, “Doc McStuffins” is a female doctor of toys. Normally the leading figures are boys, for example, Phineas and Ferb, a TV show about two siblings who are always making inventions and who have a hysterical sister always looking out for them, judging their inventions, and a girlfriend who does not participate in them.

In the history of science and technology is rare to talk about what women have done, as well the number of women in the intellectual world in the last centuries. Many significant achievements are recognized; however, it is concerning that few are from women. After research, conclusions were made that there are more female achievements than people think. For example, in 1843, Ada Lovelace became the first person in the world to write a computer program. This achievement deserves more visibility and discussion. Children who follow scientific paths learn about various notable scientists in school, yet Lovelace's contributions frequently go unmentioned. Highlighting achievements like hers is essential, as it influences how children identify role models within their fields of interest. If academic resources predominantly focus on the achievements of men, it may discourage young girls from pursuing careers in science and technology.

Merayo and Ayuso (2023) performed a questionnaire for secondary education Spanish students to understand the gender gap in the choice of STEM studies. One of the questions was role models, either close role models or famous role models. Regarding role models in their family nucleus, researchers noted that they were more familiar with males than females, as shown by their responses: father/mother, uncle/aunt, and male/female cousin. Additionally, 19.8% of male and 22% of female students reported that they did not know anyone in their surroundings who worked in these professional environments. The absence of visible female role models is a challenge, as research indicates that their presence significantly increases the possibility of students pursuing a career in one of the STEM fields (Chen et al, 2020; Pereira et al, 2024; Van Camp et al, 2019; Young et al., 2013).

On the other hand, regarding public figures, the students' answers are displayed in a word cloud in Figure 1. Both genders identified only two women: Marie Curie and Margarita Salas. However, girls tended to recognize these female scientists more frequently than boys did. Regarding role models in technology, students identified Mark Zuckerberg, Steve Jobs, Elon Musk, and Jeff Bezos. A concerning finding was that no student mentioned any female figure in this area.

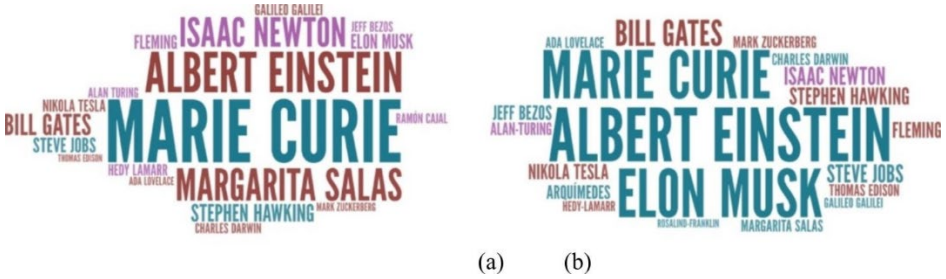

Figure 1: Famous role models that secondary students know (a) girls (b) boys.

(Source: Analysis of barriers, supports and gender gap in the choice of STEM studies in secondary education)

A 2017 study conducted by Microsoft (2017) surveyed 11.500 girls across Europe and established a strong connection between the presence of female role models and girls' interest in STEM. The findings indicate that girls who are aware of female role models display nearly double the interest in pursuing STEM disciplines compared to their peers who do not have such role models. The study also points to a significant problem, as 64% of the participants could not identify any women who stand out in STEM fields. Girls were also inquired about their family support, 81% of girls who reported receiving encouragement from their parents expressed a greater predisposition to pursue studies in STEM.

3. Statistical Evidence: Numbers in Gender Gap in STEM

According to European Statistics Eurostat (2024, 2023a), 2023b)) it is possible to see a significant gender gap regarding gender discrepancy among employed people with ICT education. Figure 2 shows the percentage distribution of men and women with the same education background in ICT who are employed throughout European countries. The disparity is significant, with most countries showing men's percentages between 80% and 90%, while women's are much shorter, often falling below 20%. Women have a higher representation in a few countries such as Denmark (DK) with 34.1%, Bulgaria (BG) with 33.4%, and Romania (RO) with 29.9%. However, countries like the Netherlands, Italy, and Switzerland have percentages as low as 12.9%, 11.2%, and 10.5%, respectively. Not all countries have data, such as Slovenia, Slovakia, Luxembourg, Latvia, and Iceland due to low reliability or not being available for publication, but even with the data provided can see the severity of the situation, where this area is overwhelmingly taken by men within the ICT sector across Europe, where the average of employed women is only 17.4%.

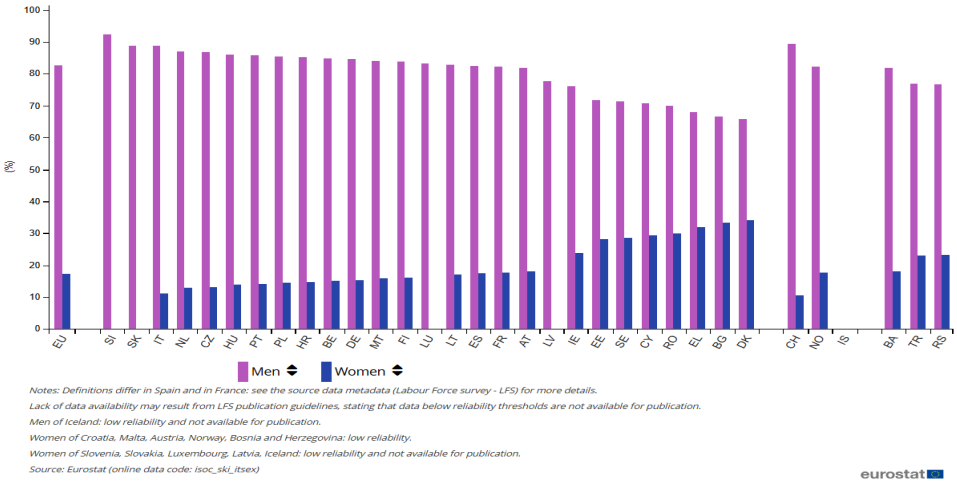

Figure 2: Share of employed people with an ICT education by sex, 2023 (Source: Eurostat Statistics, 2024)

For individuals to work in these fields, it is generally required that they obtain a degree. Figure 3 illustrates the comparison between the percentages of female and male students who enrolled in various engineering courses at the University of Aveiro in 2023. The percentage of women enrolled in the engineering degrees is very low, being the minimum percentage of women, 4.44% in Telecommunication Engineering and 37% in Aerospace Engineering. In the Computer Engineering field (ICT-related field), there is a significant gender disparity that mirrors the trends observed in Eurostat data (Figure 2). This concludes that women are underrepresented in ICT-related fields in education and the workforce, since fewer women are choosing to study these fields, it will contribute to lower employment rates.

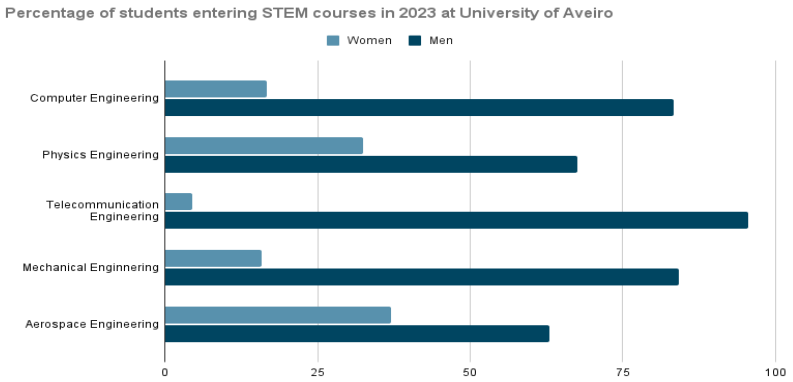

Figure 3: Percentage of students in IT, Computer Science and Engineering courses in 2023 at the University of Aveiro (Source: https://www.dges.gov.pt/guias/indest.asp?estab=0300)

According to the European Commission (EC, 2019), 53% of companies experienced difficulties in recruiting qualified ICT specialists, as only 1 in 3 STEM graduates are women and only 1 in 6 are ICT specialists in the European Union (EU). Also, they report that women earn 20% less than men. On the other side, the EC (2018) study declared that the estimated annual productivity loss for the European economy due to women leaving their digital jobs to become inactive is approximately 16.2 billion euros. This loss not only affects European companies but also impacts businesses as a whole, as women contribute unique perspectives in problem-solving and product development. By closing this gap, it would, therefore, not only support gender equity but also positively affect the economy and across EU businesses. So, the EU is implementing different strategies to retain women involved in STEM fields, for example, focusing on addressing gender stereotypes, promoting STEM education and skills, and also encouraging more women to become entrepreneurs.

4. Results and Discussion

4.1 Exploring the Causes

The causes for the existence of a gender gap in STEM may vary, such as sociocultural factors, cultural barriers, lack of opportunities, indifference to STEM fields, work-life balance, bias, and the lack of confidence in women

to pursue these careers. Another societal perception is the idea that women working in certain STEM fields are perceived as "inappropriate" for their gender, therefore women tend to not be interested in it since they don't believe they will succeed, and as said before, women usually don't like to fail.

Also, the lack of female role models for girls and women is a serious issue (Wang & Degol, 2017), as said before. When growing up it is natural to have someone to look up to and girls can withdraw their chances in STEM without one. In the early stages of life, it is important to have someone who encourages them. When talking about role models it is not only a real successful person but also an influence on media: TV shows, movies, or social media.

Another crucial factor is the environment, the fact that there are not many interesting opportunities for women makes them not have the willow of working in a male-dominated area. Sometimes, when doing research as to whether they should apply to work in a certain field or not, women see reviews such as "I always work in a man environment, so I cannot be too soft", as a participant said in research developed by Amon (2017). The existence of stereotypes in childhood and during life, even in professional careers has a strong effect, as said before.

Happe et al. (2024) address the critical need for cultural and educational shifts within the computational field. Their research, based on a questionnaire yielding 140 valid responses, identified several motivational factors that encourage women to pursue careers in computing, obstacles, and ways of attracting women to computer science. The motivation factors included personal interests, family influence, particularly from fathers, and financial opportunities. Despite these motivators, respondents also acknowledged significant obstacles, such as a lack of support and pervasive stereotypes. The authors postulate that those who view themselves or their family as the primary motivation to pursue these fields are somehow involved in computer science. In contrast, those mainly motivated by financial or job prospects usually remain outside computer science. This analysis indicates a strong need for targeted support to assist women in overcoming the barriers they face in entering this field. Therefore, the authors appeal for an early exposure of girls to computing in an enjoyable and engaging format. Additionally, they emphasize the importance of mentorship programs and the establishment of all-female classrooms. This can enable a supportive learning environment, dismantling existing stereotypes and nurturing girls' self-confidence by getting inspired by their peers or mentors. The authors conclude the article by asserting that achieving gender parity extends beyond simply matching the number of male and female workers. They emphasize that bringing more diversity expands perspectives within teams. Women can introduce new problem-solving approaches that are different from traditional male-dominated teams. Furthermore, this highlights that many women in computing science aspire to be entrepreneurial or motivated to develop projects with a social impact.

The lack of support for these women may result in missed opportunities for valuable innovations. Some studies relate the main causes of why women are not more likely to become tech entrepreneurs relate to the STEM causes. Kovaleva et al (2023) drew a map with the main causes of them not being as well represented in STEM fields – Figure 4, categorizing them into social and personal factors and illustrating their effects and implications. Social factors, such as the lack of role models, childhood stereotypes, and the idea that women prioritize their families, play a significant role. On a more personal level, society perceives women as being less willing to take risks, an action that is very common in STEM and IT startups, where taking risks or exploring uncertain fields is frequent. Women prioritize stability over risk, making entrepreneurship seem less appealing to them.

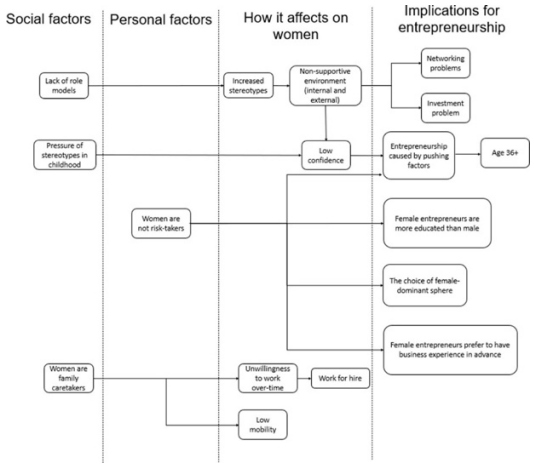

Figure 4: Main causes of women not being represented in entrepreneurship (Source: Kovaleva et al., 2023)

4.2 Identifying Areas for Improvement

Confidence matters and it's something that is built day by day in a person's life. In childhood, both school and home are the primary influences shaping a child's perspective. Children should be encouraged from birth to follow their passions and aspirations, free from traditional gender limitations. It is important to recognize that job roles should not be assigned based on gender. Is not only important what is being taught, but also the method. A study was made in middle and high schools that associated competitive and comparison environments with low levels of motivation and academic performance by students. The study case revealed that students who were stressed with academic performance by teachers, tend to avoid challenging subjects and quit more easily. On the other hand, students who were in an environment that valued effort tended to challenge themselves when, while enjoying the tasks and having higher results (Wang & Degol, 2017). Furthermore, the research results pointed those girls are leaning to pursue STEM fields if guided into hard work to address the complexities inherent in the subject (Wang & Degol, 2017). On the other side, Merayo and Ayuso (2023) defend that since girls have shown a tendency to pursue careers where they can help others if teachers in STEM subjects highlight how these fields can make a positive impact – such as using artificial intelligence to predict diseases, employing image and signal processing for diagnosis, or creating prosthetics through bioengineering – then girls may be more inclined to pursue those fields. This approach helps to demystify the stereotype of STEM being a "geek" domain.

Early exposure to computing might also attract more girls into STEM fields (Master et al, 2017; Pereira, et al. 2024) according to Happe et al (2024), based on previous studies, boys spend on average more time than girls with computers when they are home. Enabling early access to technology will improve girls' confidence and potentially encourage them to pursue related fields as they get older. Creating school, community center, or library programs designed for girls to introduce them to coding or robotics at an early age may develop their interest and confidence in ICT.

Another way to encourage girls to STEM is to introduce more female role models to school events, suggest doing research about them in school work, and organize network opportunities. Someone who young girls can be inspired and look up to when beginning to create paths for their future.

Nowadays, there are some opportunities to increase women in STEM. For example, initiatives like SheCodes or Girls Who Code[1] where there are coding workshops only for women, certain internships, research programs, job opportunities, or scholarships. In Portugal, the company E-Redes S.A. created in 2023 the Top Women Scholarship[2]. It is a one-year program dedicated to women, where besides giving financial help, they also attribute one mentor for each participant, organize multiple webinars, and can visit the company's facilities. Their goal is to promote equal opportunities within the technological field to increase the number of women pursuing technology careers and to attract female graduates with a master's degree in electrical engineering and computer science.

However, some people consider these opportunities themselves to be gender discrimination. However, these initiatives aim to encourage women to join STEM fields, like IT and Computer Science, and try to balance the scale.

5. Conclusions

The world is evolving and people are slowly changing the mentality that "some kinds of jobs are for men and some for women", but statistics don't lie and it is still an issue. This paper concludes with the information needed for more female role models in STEM fields and for society to treat boys and girls in equal ways. The underrepresentation of women is seen as a social problem; however, people need to think differently, and it can be a humanitarian issue. The fact that there are not enough women in the STEM field hinders scientific evolution, in a way they have a different perspective on the world, which can lead to new conclusions and findings.

[1] https://www.shecodes.io/ and https://www.womenwhocode.com/ .

[2] https://www.e-redes.pt/en/e-redes-top-women-scholarship.

Based on the research developed in this paper, some strategies to close this gap can be:

- Introducing more female role models;
- More promotion on social media;
- More programmes for women and mentoring;
- Scholarships for young girls and women in STEM field;
- Change behaviour in classrooms, preferring an environment that values effort over grades, rather than a competitive classroom;
- Educating children in equal ways, letting them follow their passions.

Nevertheless, this paper is not trying to devalue men or appeal to feminists. It appreciates the existence of both genders in equal ways and wants to encourage more women to decrease the gender gap. The world needs to have more women aware of their capabilities and actively participate in STEM and ICT fields. This emphasis is not meant to overlook men but rather to foster equality for everyone and embrace the richness that diversity brings. With this article, we hope to raise societal awareness about the importance of addressing the gender gap early on, particularly through a different perspective on children's education, as they are our future.

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