Inequalities for Women in Science, Technology and Innovation

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Abstract: There is still a tangible inequality between men and women in many areas of daily life around the world, including professional fields and educational careers. The objective of this study was to analyze the different inequalities in Europe and third countries in America, Asia and Africa regarding the involvement of women and men in education and employment. This study focused on the areas related to Science, Technology and Innovation (STI), three of the most relevant and important areas for the future development of society. The study presented in this paper started with the initial question: "Are there inequalities between women and men in the fields of Science, Technology and Innovation?" This question was followed by an in-depth examination of datasets and studies on women and men who are learning, working, or hold leadership positions in the STI fields. Data and numbers were collected on the workforce, students in higher education, and professional fields. These served to determine and verify the state of the art for women in the fields of STI. Based on the results, presented in the paper, statements can be made regarding inequalities for women in the field of STI. Several efforts are being made in order to promote gender equality in STI. In fact, this has become a strategic issue in Europe, since the Council of the European Union, in its conclusions, invited the Commission and the Member States to consider including the gender perspective within the policy dialogues in bilateral and multilateral agreements with third countries in the STI area. Moreover, several initiatives have been implemented in recent years as part of the strategy for the European Research Area to promote gender equality in research and innovation. One of these initiatives is the Gender STI project, a European research-funded project that aims to integrate gender perspectives in STI into dialogues between Europe and third countries. As part of the initial activities of the project, this study aims to build a deep understanding on the current status of gender equality in STI in these regions and how the gender perspective is currently addressed in policy dialogues.

Keywords: gender, women in STI, higher education, profession, STI

1. Introduction

Nowadays, there still exist inequalities for women in many areas including the professional sector. This manuscript analyses the inequalities found in the fields of Science, Technology and Innovation (STI), through the study of relevant data sources from six European countries and ten countries from America, Africa and Asia. The paper confirms that although the worldwide population is overall distributed 50/50 between men and women, employment rates, study of careers related to STI and participation in decision making in STI is lower in women than men, with differences among the studied countries.

2. Related work

Women are still underrepresented in the STI fields. According to a report entitled “The Researcher Journey Through a Gender Lens” (De Kleijn et al., 2020), clear disparities still exist although the number of women participating in research has significantly increased in recent years. The STI fields continue to be male dominated working areas. Less than 30 percent of researchers worldwide are female, and only 30 percent of female

students choose to enter a field related to science, technology, engineering, or mathematics (STEM) (United Nations, 2021).

At the graduate level, women are also underrepresented; a recent study showed that only 29, 19, 23 and 34 percent of women received a PhD in mathematics and statistics, computer and information sciences, engineering and physical and technological sciences, respectively (Wang and Degol, 2017). Furthermore, many women do not choose to pursue an education in a STEM field, meaning that fewer women than men graduate from university specialising in a STEM field. In fact, two recent studies indicated that 34 percent of males as compared to 12 percent of female graduated with a degree in a STEM field (Card and Payne, 2021; Poggesi et al., 2020). This gap is broadened by gender stereotypes and cultural factors that affect gender equality, and deepened by the fact that role models and female mentors are generally lacking in this field. This gap, in turn, affects the proportion of women employed in STI fields: Fewer women than men hold positions of responsibility in STEM fields. Nevertheless, increasing the visibility of these female entrepreneurs could inspire and empower young women who would like to start or pursue a career in the STEM fields. A positive correlation has been observed between having female role models and the level of involvement of young girls in STEM. Studies show that the proportion of women graduates in STEM increases when the proportion of females on the faculty increases (Bottia et al., 2015).

In the field of innovation, the underrepresentation of women plays a significant role. Fewer women in STEM careers translates – among other things – to restrictions in creativity, innovation and competitiveness in innovative businesses (Soler, Alvarado and Nisperuza, 2020). Clear disparities can also be observed in the area of inventor teams: These teams are composed of only male members in 47 percent of the cases and by one man alone in 33 percent of the cases (She Figures, 2019). These aspects impact how solutions to current global challenges are found, such as climate change, diseases and access to water. Many significant innovations will occur in the future, and people with the right skills are required to create these innovations. If women are underrepresented in STEM fields, many talented individuals will fail to participate in solving these challenges and, consequently, many solutions may never be considered (Corbett and Hill, 2015).

Furthermore, women are clearly underrepresented in professional positions and especially in leading positions in research (Comisión Europea, 2008). Where decision-making occurs and where further steps are taken, women still do not have enough opportunities to contribute. In addition, women in leadership positions also take on the role of reference models and contribute to the visibility of women in the STI fields.

Several reasons for promoting women in the STI fields exist. One of these reasons is that we need more scientists; we simply cannot afford not to use half of the population in this field as a workforce (Polcuch, Brooks and Bello, 2018). For this reason, it is essential to foster the engagement of women in STEM, to create a more gender-balanced future generation of STI professionals and to position this issue as a key part of current political agendas (Smith, 2011).

3. Methodology

First, data were collected on gender and STI fields, namely these data needed to refer to both gender and STI. The STI fields chosen were the science, technology, engineering and mathematics (STEM) areas to ensure the comparability of the data. These areas included the natural sciences, mathematics and statistics, information and communication technologies, and engineering, manufacturing and construction. The data on human resources in STI needed to refer to scientists and engineers studying in scientific or technological areas or individuals employed by science and technology companies.

To assess the differences between women and men in STI fields, data were gathered from data sources in the third countries of Argentina, Brazil, Canada, Chile, China, India, Mexico, South Africa, South Korea and the USA, as well as six EU countries (i.e. Austria, Italy, Finland, France, Portugal, Spain). These formed the core reference group in this study. These differences indicated the distribution of women and men:

- in fields of employment
- in education (university) in STI fields,
- among PhD graduates in STI fields,
- in human resources in STI and

- in leading positions (regardless of the professional field).

Second, data were collected from Eurostat regarding the 2019 populations of men and women registered in each country (Eurostat, 2020). Data for 2020 for the non-EU countries were collected from the World Bank Open Data Catalog. Data for the numbers of men and women employed in EU countries in 2019 were also extracted from Eurostat (Eurostat, 2020), and 2020 data for the numbers of men and women employed in the non-EU countries were obtained from the World Bank Open Data Catalog. The analysis of the latter data enabled us to identify differences in employment based on the population. This result supported the evaluation of the subsequently collected data.

To collect data on the participation of men and women in STI fields, we considered these fields as similar to STEM (science, technology, engineering and mathematics) fields.

The data collected for the STI fields was divided into three categories based on the gender division:

- 1. education (university) (OECD Stat, 2021)
- 2. PhD graduates (European Institute for Gender Equality, 2021a) and
- 3. human resources (European Institute for Gender Equality, 2021b) and (European Institute for Gender Equality, 2021c).

In addition, data were obtained on women and men in leading positions. Here, insufficient gender data were available in the STI fields (STEM related), so these data were generally determined regardless of the professional field.

The data were collected by conducting extensive research via various websites that hosted databases. Among others, the websites of the European Institute for Gender Equality (https://eige.europa.eu), OECD.Stat, (OECD Stat, 2020), European Commission (2020), World Bank Open Data Catalog (The World Bank Data, 2021) and UIS.Stat were used.

To obtain a worldwide overview, data were provided by the Gender STI project to complement comparable data from the aforementioned sources. The Gender STI project places a focus on gender aspects in bilateral and multilateral agreements made in the STI fields. Consequently, organisations in Argentina, Brazil, Canada, Chile, China, India, Mexico, South Africa, South Korea and the USA gathered equivalent country data. This coverage made it possible to obtain a nearly worldwide overview of the status of inequalities between women and men in STI.

4. Results

These analyses were based on data collected in the EU countries of Spain, Finland, Portugal, Austria, France and Italy, as well as the third countries of Argentina, Brazil, Canada, Chile, China, India, Mexico, South Africa, South Korea and the USA. First, the number of women and men living in the respective countries in 2019 was determined. We asked the key question: *What is the distribution of women and men living in the respective country?*

In 2019, 51 percent of the population of the EU 28 states consisted of women. In Spain, Finland, and Austria, just under 51 percent of the population consisted of women and, in Italy, this proportion was slightly more than 51 percent. In France, 51.7 percent of the inhabitants were female, and in Portugal, 52.8 percent (Eurostat Data Browser, 2021a).

In third countries, the populations of Argentina and Mexico consisted of slightly more than 51 percent women; the populations of Chile, South Africa, Canada, the USA and Brazil consisted of more than 50 percent women; South Korea's population consisted of 49.9 percent women; China's population consisted of 48.7 percent women; and India's population consisted of 48 percent women (The World Bank Data, 2021).

We then asked a second question of interest: *Are more women or more men employed in STI fields?* To answer this question, we first determined the employment status of women and men in the countries of interest; then, we examined their employment rates in the STI fields. Despite the fact that men and women were nearly equally

represented in the populations of the countries in which data were collected, more men than women were employed in all countries. Table 1 shows the percentage of employed women and men in these countries.

Table 1: Gender bias in employment rate (Eurostat Data Browser, 2021b)

Countries	Employment 2019 women	Employment 2019 men
EU 28	68.2%	79.6%
Spain	62.1%	74.0%
Finland	75.8%	78.5%
Portugal	72.7%	79.9%
Austria	72.4%	81.2%
France	68.1%	75.2%
Italy	53.8%	73.4%
Argentina	59.0%	80.0%
Chile	59.0%	79.0%
South Africa	54.0%	66.0%
Canada	75.0%	82.0%
USA	67.0%	78.0%
Mexico	48.0%	82.0%
Brazil	61.0%	80.0%
India	22.0%	80.0%
South Korea	51.0%	71.0%
China	68.0%	82.0%

In Table 1, the Eurostat Data Browser was used to obtain data for the European countries. Data for the year 2019 were extracted, and the percentage of employed women and men aged 20–64 was determined in relation to the total population. Data for 2019 was extracted from the World Bank Data for the ten third countries, and the percentage of employed women and men aged 15–64 was determined in relation to the total population. In the EU, women are employed 11.4 percent less frequently than men on average. However, we observed strong differences among the individual countries, illustrated by the comparison of the six European countries. Finland performs the best with a difference of only 2.7 percent between the male and female employed populations, while 19.4 percent fewer women are employed in Italy. However, these results are independent of the professional field. The population average in the EU is distributed almost 50/50, whereby the percentage of women in the population tends to be higher than the percentage of men. Therefore, the results clearly show that fewer women than men are actually employed, indicating the presence of inequality. Among the third countries, the percentages of employed women and men in Canada, the USA and South Africa are closer to the European average, while the other seven show clearly greater differences in employment status. India represents an outlier, as 58 percentage fewer women were employed in 2019 than men; this means that only 22 percent of the women were employed, while 80 percent of the men were employed. The results for Mexico and China also indicate starkly striking inequalities. Brazil, Chile, Argentina and South Korea show a difference of about 20 percent. These findings illustrate the clear differences among the various countries, but one fact remains the same in all countries: on average, fewer women than men are employed.

In order to gain an understanding of the gender balance in STI, data related to gender and STI fields were collected and analysed to assess the current status. This research was carried out in three stages. First, we determined how many women and men were enrolled at tertiary education institutions in STI fields. Second, we assessed the proportions of male and female PhD graduates in STI fields. Third, we calculated the percentage of women in STI fields on the basis of human resources data. Two specific areas were considered here:

- 1. Human resources in science and technology fields and
- 2. Human resources in the form of scientists and engineers.

Table 2: Gender bias in STI fields for EU (OECD.Stat, 2021) and (European Institute for Gender Equality, 2021a).

Countries	in Education 2018 women	in Education 2018 men	with PhD 2018 women	with PhD 2018 men
EU 28	-	-	0.01%	0.01%
Spain	11.47%	36.30%	0.06%	0.07%
Finland	12.88%	50.89%	0.04%	0.07%
Portugal	17.91%	41.82%	0.04%	0.04%

Countries	in Education 2018 women	in Education 2018 men	with PhD 2018 women	with PhD 2018 men
Austria	9.55%	28.08%	0.03%	0.06%
France	14.30%	39.73%	0.03%	0.06%
Italy	16.38%	35.17%	0.02%	0.03%

The values in the columns labelled “in Education 2018 women” and “in Education 2018 men” in Table 2 reflect the percentages of women and men enrolled at tertiary education institutions who chose to study in an STI field in the year 2018. Figure 1 shows the distribution of women and men in tertiary education in the European countries based on data presented in Table 2.

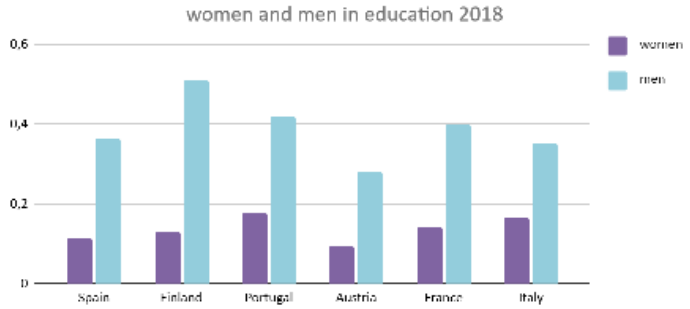

Figure 1: Distribution of women and men in tertiary education in EU countries.

Data shown in the columns labelled “with PhD 2018 women” and “with PhD 2018 men” in Table 2 represent data on graduates aged 25–34 who graduated with doctoral degrees in fields of science, mathematics, computing, engineering, manufacturing and construction in 2018. Figure 2 shows the distribution of women and men who graduated with a PhD in 2018, based on data presented in Table 2.

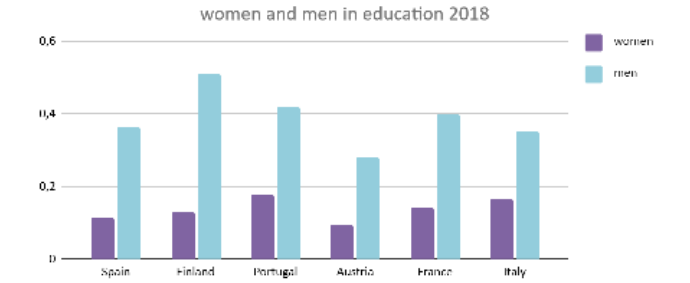

Figure 2: Distribution of women and men with a PHD in 2018 in EU countries.

Table 3 reflects the percentages of women aged 15 to 74 who were employed in 2019 in the fields of science and technology or who were working as scientists and engineers.

Table 3: Gender bias in STI fields regarding human resources in the EU
(European Institute for Gender Equality, 2021c)

Countries	Human Resources 2019 (% women)	
	Science and Technology	Scientists and Engineers
EU 28	51.99%	41.65%
Spain	50.68%	50.39%
Finland	52.93%	70.6%
Portugal	53.3%	48.22%
Austria	52.67%	46.65%
France	31.39%	41.86%
Italy	47.19%	34.51%

Of all those who chose to pursue tertiary education, males most commonly decided to enter an STI field in Finland (i.e. 50.89 percent), whereas only 12.88 percent of women in Finland chose to enter an STI field. In order for an equal number of men and women in STI tertiary education in Finland in 2019, 38.01 percent more women would have needed to enter an STI field. This inequality in Finland is also reflected by the numbers of male and female PhD graduates. Therefore, it is all the more interesting that Finland is the best performer in the human

resources category. In terms of overall human resources, 52.9 percent of the employees in science and technology in 2019 were women, while 70.6 percent of women were working as scientists or engineers.

However, the results for Finland do not represent the European standard, as on average only 41.65 percent of people working as scientists and engineers in 2019 were female. In many countries, the differences between women and men in the STI fields were even higher. Results for Spain also lie well above the EU average for human resources at 50.39 percent, followed by those for Portugal, Austria and France. In these countries, the percentages of women working in the STI field were just above the EU average. The results from some countries, however, underline the inequality between female and male scientists and engineers. One example is Italy, where only 34.51 percent of the scientists and engineers were female in 2019. Regardless of their future career field, clear differences were observed between women and men in terms of their choice of education. This study identified a gender gap for education in Finland (38.01 percent fewer women in STI education), France (25.43 percent fewer women in STI education), Spain (24.83 percent fewer women in STI education), Portugal (23.91 percent fewer women in STI education), Italy (18.79 percent fewer women in STI education) and Austria (18.53 percent fewer women in STI education). Finland has the largest gap, with significantly fewer women than men opting to pursue technical tertiary education. The gap is smallest in Austria, although the number of people interested in pursuing education in the STI fields is small overall. These results are shown in Table 2. In assess the gender gap regarding education and human resources in third countries, an analysis of worldwide data was conducted. The availability of these data was sometimes highly limited, which is in itself an indication of the need to pay more attention to gender aspects in STI. Table 4 shows the data used for the evaluation of the gender gap in education and human resources in STI fields.

Table 4: Gender bias in STI fields, 10 countries (OECD.Stat, 2021), (UNESCO, 2021a) and (UNESCO, 2021b)

Countries	in Education 2018 women	in Education 2018 men	with PhD 2018 or 2017 women	with PhD 2018 or 2017 men	Human Resources Researcher (% women)
Argentina	33%*	67%*	0.03%	0.03%	54.10%
Chile	6.88%	39.47%	0.01%	0.02%	34.40%
South Africa	-	-	0.03%	0.04%	44.90%
Canada	12.14%	36.77%	-	-	-
USA	11.33%	29.87%	-	-	-
Mexico	14.97%	38.66%	-	-	33.00%**
Brazil	10.69%	29.97%	-	-	-
India	27.80%	38.02%	-	-	-
South Korea	14.31%	45.06%	0.07%	0.1%	20.40%
China	-	-	-	-	-
*from BID-Argentina					
**data from 2013					

Due to the limited accessibility of some data, only part of the table is filled. The columns labelled “in Education 2018 women” and “in Education 2018 men” display data obtained from the same source as the EU data, making the values comparable with each other. These data indicate the percentages of women and men, respectively, who chose to pursue higher education in an STI field. The values are very similar to those for the countries shown in Table 2. Figure 3 shows the different distribution of women and men in tertiary education in 2018 in Chile, Canada, the USA, Mexico, Brazil, India and South Korea, based on data presented in Table 4.

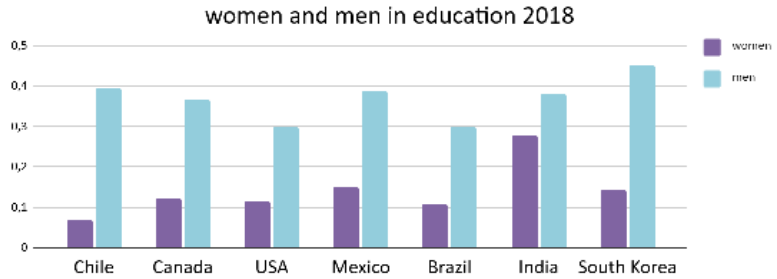

Figure 3: Distribution of women and men in tertiary education in 2018.

The proportion of men interested in pursuing higher education in an STI field is similar to the proportion seen in the six EU countries. Differences can be seen among the proportions of women, whereby Chile has an even

lower proportion of women (i.e. 6.88 percent) and India has a much higher proportion of women (27.8 percent) who opted to pursue higher education in an STI field. Nonetheless, these data indicate that the highest female percentage (i.e. 27.8 percent in India, Table 4) is smaller than the lowest male percentage (i.e. 28.98 percent in Austria, Table 2). This gap clearly shows the inequality between women and men pursuing education in STI fields. Far fewer women than men received education that would professionally qualify them to work in an STI field in 2018. The columns labelled "with PhD 2018 or 2017 women" and "with PhD 2018 or 2017 men" show the proportion of women and men who received graduate degrees comparable to a PhD (UNESCO, 2021a). Again, fewer women than men always received advanced degrees in STI fields. The values for Argentina, Chile, South Africa and South Korea are above the EU average. South Korea stands out, because as many as 0.13 percent of men received a PhD in an STI field. The proportion of women is also particularly high here, although fewer women were initially enrolled in tertiary education than men. Apparently, women who pursue this education are also more likely to graduate with an advanced degree in this country.

The human resources column reflects the proportion of women in STI fields (UNESCO, 2021b). The data were collected in 2017 and 2018 and, for Mexico, in 2013. Argentina has a very high share of women in research (54.1 percent), while the data for South Africa are similar to the European average, insofar as the data can be compared. The data for Chile, Mexico and especially South Korea clearly show a gap between women and men in STI research fields. However, due to a lack of data, no overall worldwide statement can be made; therefore, additional data were obtained from the United Nations. The results of the analysis of these UN data indicate that the proportion of female researchers is less than 30 percent worldwide (United Nations, 2021).

Third, we determined the proportion of women in leadership positions. To do so, it was necessary to neglect the restriction of STI fields due to the lack of data. Figure 4 presents the distribution of women and men in leadership positions worldwide. (Eurostat, 2021) and (UN WOMEN 2021)

In the EU 28 countries, 28.8 percent of leadership positions were held by women in 2019. France stands out particularly in the business field, with 45.2 percent female leaders.

The USA performs great with 40.7 percent of women in leadership positions; this percentage does not surpass France's proportion of women in leadership positions, but is clearly higher than the EU average. Argentina, Chile and South Africa have percentages of women in leadership positions which are similar to the EU average of 28.8 percent, and South Korea and India score very poorly at 14.5 percent and 13.7 percent, respectively.

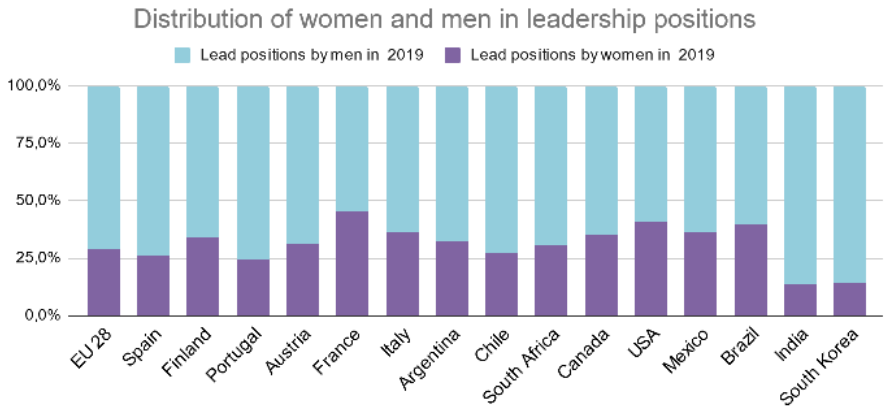

Figure 4: Distribution of women and men in leadership positions worldwide

5. Conclusion

The research study shows evident disparities between women and men studying and working in science, technology, and innovation (STI). Regardless of the scientific field, female scientists only represent 41.65 percent of the EU average. Less than 30 percent of researchers worldwide are female. Only 30 percent of female students chose to study an STI field. In addition, the findings reveal that women are poorly represented in leadership positions, regardless of the field of STI. A worldwide overview for women STI fields was carried out by collecting data from EU countries of Finland, France, Italy, Spain, Portugal, and Austria, as well as non-EU countries of Argentina, Brazil, Chile, China, Canada, India, Mexico, South Africa, South Korea, and the USA. The wide range

throughout the different countries of this current research study advances gender research to reduce gender inequalities.

Consequently, the findings provide a foundation for meaningful systematic change in gender equality. The results support international governmental initiatives as a basis for (new) monitoring purposes. National and international governmental monitoring and documentation could counteract the limitation of data of non-binary genders or women in leadership in STI fields. The differences among the countries for women in leadership positions show the potential in future studies by comparing different countries, which could detect the source of the gender disparities across various nations. Researching the drivers of gender inequality in the STI field in different countries might reveal cultural norms, systemic policies, or social structures that may prevent the advancement of women in STI fields.

Future initiatives and projects like Gender STI address the gender gap. These projects aim to address policy dialogues in the European research area to counteract gender inequalities. Further research concerning the mapping of gender equality in bilateral and multilateral agreements will help verify the state of the art of gender equality in STI. Building a community of practice and addressing the issues of gender inequalities in a political context helps foster gender equality in STI.

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