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Analysis of the Scientific Production of Men and Women in STEM: UTPL Case Study

Yasmany García-Ramírez1[0000-0002-0250-5155] and Soledad Segarra-Morales2[0000-0001-9657-4532]
1,2 Universidad Técnica Particular de Loja, Ecuador, ydgarcia1@utpl.edu.ec, mssegarra@utpl.edu.ec

***Abstract*– The gender gap in science, technology, engineering, and mathematics (STEM) fields remains a persistent issue globally. Despite recent progress, significant disparities continue to exist. This study aims to identify and analyze the gender gap in scientific publications among researchers in a specific university located in southern Ecuador. A sample of 188 male and female faculty members indexed in the Scopus database, spanning a 10-year period, was utilized. The study focuses on a specific university located in Ecuador and analyzes the gender gap in scientific publications within STEM. Women excel in education and management, while men focus on biology and ecosystems. Men publish more in journals/books, and women in conferences. Implicit bias, lack of mentorship, and work-life balance issues contribute to the gender gap. Effective strategies must be developed to promote gender equality in STEM fields, given the underrepresentation of women at higher academic levels and the potential disadvantages they face in finding suitable research partners.**

Keywords Gender gap, research productivity, gender equality in STEM.

I. Introduction

Women have historically faced a worrying gap in science and technology-related disciplines, generally known as Science, Technology, Engineering, and Mathematics (STEM) [1]. Despite progress in recent years, significant gender disparities still persist [2, 3]. One area where these disparities are evident is in the publication of scientific articles [4]. Academic publications serve as essential channels for disseminating research findings to the global scientific community [5], and several studies have investigated this issue. The results show that women are underrepresented in scientific publications compared to men [6–9].

For instance, a study conducted in Italy during the first wave of the COVID-19 pandemic found that only 22.2% of the articles were authored by women as the first author and 18.1% as the last author. Female authorship was less frequent than male authorship regardless of the type of study, number of co-authors, type of affiliation, and field of specialization [10]. Another study conducted in Italy on political science publications found that the proportion of published articles written by female authors is lower than that of male authors, and there is little collaboration between men and women [8].

Similarly, a study conducted in Turkey on academic publications found that the ratios of female authors per article, female first author, female corresponding author, and female last author were lower in the SCI-E/SSCI and ESCI groups compared to the other international index groups. In all article types, the rate of women as the last author was lower than the rate of women as the first author [9]. Moreover, a study conducted in South America found that male authors outnumbered female authors 2.24:1, with particularly low levels of authorship by females in studies in the area. While male first authors also outnumbered females 1.95:1, male last authors outnumbered females 3.30:1, and male sole authors outnumbered females 5.29:1 [11].

Differences in research productivity by gender may vary depending on academic fields [12]. Despite recent efforts to promote gender equality, men still outnumber women 2 to 1 in the scientific workforce and, on average, have more productive careers and higher impact [4]. Furthermore, men tend to have longer publishing careers and lower dropout rates than women [13]. The gender gap is particularly pronounced in authorship positions associated with seniority, and prestigious journals tend to have fewer women authors [14]. Additionally, men are invited to submit papers to journals at approximately twice the rate of women [14]. Several factors contribute to this gender gap, including implicit bias, lack of mentorship, and work-life balance issues [4]. The underrepresentation of women at higher academic levels in many academic institutions may further contribute to this gender selection bias, potentially placing women at a disadvantage in finding suitable research partners and explaining their lower publication productivity [15]. This trend is also observed in STEM (Science, Technology, Engineering, and Mathematics) fields.

The gender gap in STEM is a well-known issue that affects regions and countries worldwide. The representation of women in scientific and technological careers dates back to the 1960s, and although progress has been made, women are still underrepresented in these fields [16]. Academic women publish less and receive fewer citations in STEM [17]. Several studies have been conducted to analyze the causes of the gender gap in STEM and suggest ways to overcome it. Some of the main barriers identified include gender stereotypes, lack of female role models, and obstacles during different developmental stages [16]. Additionally, research has shown that activities that could help close the gender gap in STEM areas are often penalized upon evaluation, which discourages female researchers from pursuing these activities [18].

To address the gender gap in STEM, parents, teachers, and the community must actively support and encourage females to enter STEM fields [16]. Motivational programs that emphasize the strengths and possibilities of success in STEM

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careers can also help capture the interest of female students [19]. It is important to note that the gender gap in STEM is not consistent across all fields. For example, women are well-represented in science but not in technology or engineering [20]. The inconsistent gender gap highlights the importance of causes that produce segregation within both STEM and leadership as children and teens develop into young adults who enter career paths in these fields [20].

Overall, the gender gap in STEM is a complex problem. Educators can play a role in creating gender-inclusive STEM classrooms by implementing strategies such as providing female role models, creating a gender-balanced environment, and using a gender component in the method of education and training [21]. In this study, the gender gap in scientific publications within the STEM field is identified and analyzed among researchers attempting to publish their research findings at a specific university located in southern Ecuador. The study utilized a sample of 188 male and female faculty members indexed in the Scopus database, covering a 10-year timeframe. The main findings reveal a gender gap in scientific production among university professors, with fewer women occupying top publication positions. Gender barriers hinder women's representation in top positions. Further research is necessary to comprehend and address the underlying causes and to develop effective strategies.

II. Methodology

For this study, the scientific production of male and female professors from the Universidad Técnica Particular de Loja (UTPL) was analyzed. This university is located in southern Ecuador. Specifically, the study focused on professors within the STEM fields who are registered in the Scopus database. A descriptive statistical analysis was performed, which is described below.

A. Database

To conduct this quantitative analysis, the Scopus database was used with a 10-year timeframe, spanning from 2012 to 2022. During this period, 490 faculty members (out of over 1000) managed to index their articles in this database. Within this group, 188 faculty members belong to the STEM field. The following data was obtained from these faculty members: number of publications, number of citations, number of articles in journals, number of conference papers, number of books or book chapters, areas with the highest contributions, Field-Weighted Citation Impact (FWCI), percentage as first author, highest postgraduate degree and hours of dedication to research.

B. Quantitative analysis

In this study, using some statistical techniques we examine several factors: the number of publications, citations, types of publications, areas of contribution, Field-Weighted Citation Impact (FWCI), authorship trends, highest postgraduate degree, assigned profiles at the university, and dedication to research. This analysis allowed us to gain insights into the productivity and research patterns of these professors.

- Firstly, the relationship between the number of publications and the number of citations over the 10 years *was* analyzed. A scatter plot was used, with linear regression equations as a reference.
- Subsequently, a box and whisker plot were created to observe the differences between the types of publications made by the professors.
- Next, a word cloud was generated to visualize the areas in which faculty members have made the greatest contributions. This analysis aimed to identify differences in the topics addressed by each gender.
- For the FWCI analysis, the values for each researcher were averaged, and an Interval Plot was created. These plots allow for the evaluation and comparison of confidence intervals for the means of the groups. An Interval Plot shows a 95% confidence interval for the mean of each group.
- To analyze the faculty members' participation as first authors, the percentage of times each researcher appeared as the first author of their publications was calculated individually. A box and whisker plot was then created to analyze the trends between genders.
- Additionally, an analysis was conducted based on the highest postgraduate degree, the assigned profile at the university, and dedication. In these cases, box and whisker plots were also used.

III. Results

This section presents an in-depth analysis of various key factors related to the scientific production of faculty members from the UTPL. The section begins with demographic results, providing insights into the gender distribution among the faculty members. Subsequently, the relationship between the number of publications and citations is examined, shedding light on the impact and visibility of their work. The section then delves into the type of documents published by the faculty members, exploring the diverse formats used to disseminate their research findings. Furthermore, the areas of greatest contribution are identified, offering a comprehensive understanding of the research focus and expertise of the faculty members. The Field-Weighted Citation Impact (FWCI) is subsequently analyzed, providing an assessment of the relative influence and impact of their research within their respective fields. The section also investigates the faculty members' involvement as first authors in their publications, revealing trends and patterns in authorship. Finally, the postgraduate degree titles held by the faculty members are examined, shedding light on their educational backgrounds and expertise.

A. *Demographic results*

Out of the 188 faculty members, 65 were women (35%) and 123 were men (65%). This initial data is interesting because, in that university, slightly over 50% of professors are female based on the demographic distribution. Additionally, at a national level, the proportion of men and women is approximately 50%.

B. *Number of publications versus the number of citations*

Regarding the total publications over 10 years, among the top twenty most prolific faculty members, women occupy the third, fifth, and eleventh positions. The rest of the positions are filled by men. In the bottom twenty positions, there are eight women and twelve men. On the other hand, among the top twenty faculty members with the most citations over 10 years, there are five women in the fourth, twelfth, thirteenth, fourteenth, and fifteenth positions. In the bottom twenty positions, there are nine women. The faculty member with the highest number of citations has 2593 citations over these 10 years. This professor has almost triple the number of citations of the next person on the list (738), who is also a man. The atypical faculty member was removed to analyze the relationship between publications and citations, and Figure 1 was created.

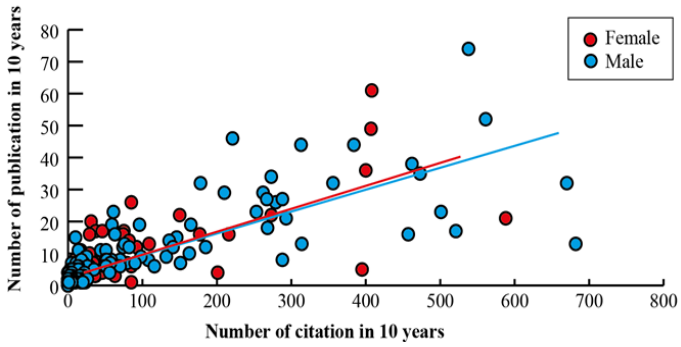

Fig. 1 Number of publications and citations over 10 years for men and women in the study.

In Figure 1, no notable variations in the trends of the linear regression lines are observed between both groups of individuals. However, when examining the dispersion of data, it becomes evident that there are fewer women in the top positions, as mentioned earlier. The majority of individuals, regardless of gender, are clustered within the range of 0 to 30 publications and up to 200 citations. However, beyond this range, the presence of women decreases significantly, in contrast to men who are represented across all values in the figure.

C. *Type of published documents published*

To analyze the type of articles published, a box and whisker plot was created, as shown in Figure 2. In terms of the number of articles published in journals, it is evident that men have a higher publication rate compared to women. The average for men was 7.5 articles, while for women it was 4.1 articles, resulting in a difference of 2.4 articles per person. Additionally, there are more outliers among women. Although there are exceptional women who deviate from the general trend, their publication levels still do not reach the same magnitude as men.

On the other hand, when considering the number of articles published in conferences, the outlier professors are similar for both groups. However, women tend to publish more in conferences than men. The average for women is 4.9 conference articles, while for men it is 2.9 articles, resulting in a difference of 2 conference articles per person.

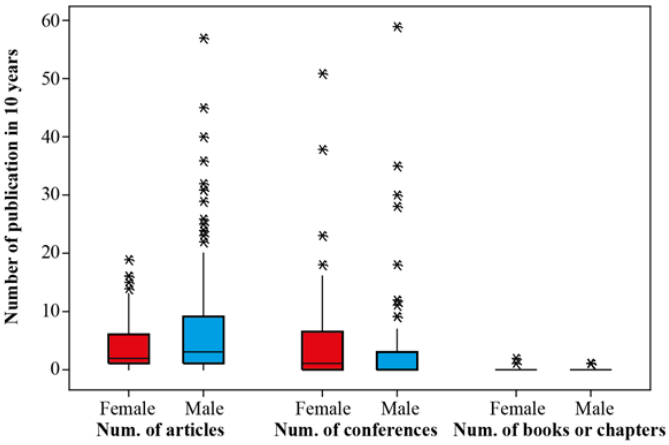

Fig. 2 Number of publications in 10 years by type of publication for men and women in the study.

Lastly, in terms of books or book chapters, both groups demonstrate lower publication rates compared to other types of publications. However, the average for men (0.10) is double that of women (0.05).

Overall, these findings provide valuable insights into the publication patterns of men and women, highlighting differences in the number and types of articles they publish in journals, conferences, and books or book chapters.

D. *Areas of the greatest contribution*

The Scopus database provides information on the major contributing areas for each author with publications indexed in its database. Utilizing this data, a word cloud was generated, and the counting results are presented in Table 1.

TABLE I
THE NUMBER OF WORD COUNT AREAS FOR BOTH MEN AND WOMEN.

Male areas	Frequency	Female areas	Frequency
Ecosystem	5	Education	5
Ecuador	5	Management	5
Software	5	Systems	4
Coal	4	Laboratory	3
Diterpenes	4	LabVIEW	3
Management	4	Learning	3
Stability	4	Software	3
Abietane	3	Virtual	3

Andes	3	Agile	2
Antioxidant	3	Agriculture	2

Upon examination, it is evident that both groups contribute to software and management, although not in the same proportion. Notable differences can be observed in the choice of words mentioned by male and female professors. Male professors tend to mention words related to their field of specialization, such as "ecosystem," "software," and "stability." On the other hand, female professors tend to mention words more associated with education and management, such as "education," "management," and "systems." These findings indicate that while there are common areas of contribution between male and female professors, their choice of words reflects their distinct areas of expertise and research focus.

In terms of the areas of contribution in publications, we counted the specific areas to which the publications contribute. On average, men (4.9) contribute to a greater number of areas compared to women (4.4). Additionally, the maximum number of areas for men is 28, while women reached a maximum of 20 areas.

F. Field-Weighted Citation Impact (FWCI)

The Field-Weighted Citation Impact (FWCI) measures the impact of citations in scientific production within a particular field of study, relative to the global average for that field.

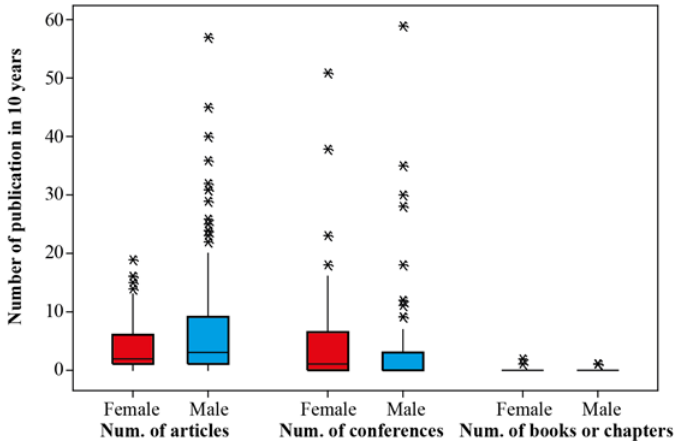

Fig. 3 Interval plot for the average FWCI (Field-Weighted Citation Impact) for men and women in the study.

The FWCI is designed to provide a more accurate measure of research impact than traditional citation metrics, which do not account for differences in citation practices between fields. An FWCI greater than 1 indicates that the citation impact of research work in a specific field is higher than the global average for that field. Average FWCI values were obtained for researchers, and an interval plot was created, as shown in Figure 3. In this case, it was observed that women have a higher impact than men, despite the mean values being close. It can also be said that there is a group of women whose publications have a greater impact compared to men.

G. Order of Authorship

It is generally considered that a researcher has made a greater contribution to the research when their last name appears in the first position of authorship. Therefore, the percentage of times the researcher appears as the first author in their publications was calculated for each profile. Subsequently, a box and whisker plot were created to analyze the trends (see Figure 4). Overall, women appear as the first author more frequently than men.

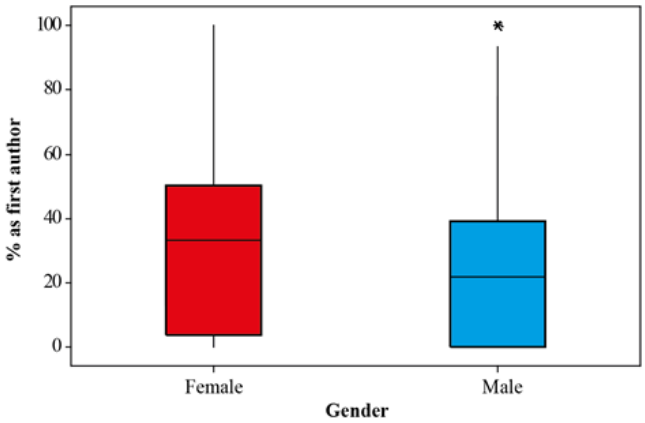

Fig. 4 Box and whisker plot for the involvement of professors as first authors.

H. Postgraduate degree diploma

Regarding the highest postgraduate degrees, a box and whisker plot was created (Figure 5) to examine the trends. Individuals with a doctorate (Ph.D.) have a higher number of publications compared to female doctors. However, female researchers with a master's degree have slightly higher production than male professors.

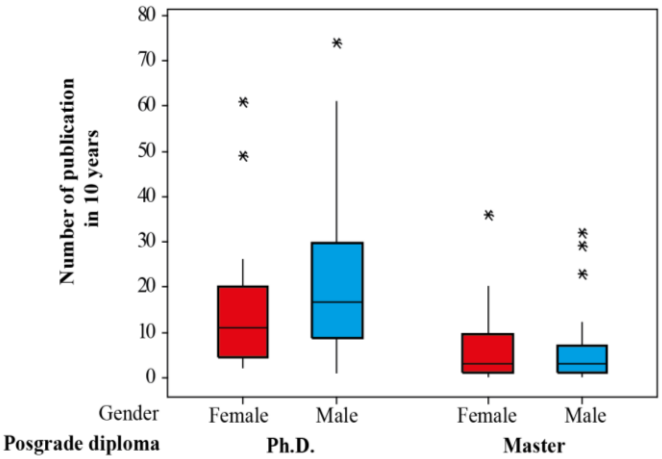

Fig. 5 Box and whisker plot for the highest diploma of the professors.

IV. Discussion

The objective of this study was to examine and understand the differences in scientific publications between genders in STEM fields, with a specific focus on UTPL professors. The results indicate that male professors publish more articles and receive more citations compared to female professors in the university as seen in previous literature. It was observed that men tend to publish more articles in journals, while women publish more in conferences. While there is no clear evidence that women publish more in conferences than men, it is worth noting that conference policies can have an impact on author diversity and experience. For example, a study of 56 computer systems conferences found a poor balance in the gender and geographical distributions of authors, but a more balanced spread across sectors, experience, and English proficiency [22].

Furthermore, men publish more books or book chapters than women. There is limited research on gender differences in publishing books or book chapters in STEM fields. However, a study conducted in 2017 analyzed data on 1633 faculty members who authored or edited 4835 scholarly books in the top 50 U.S. English Ph.D. departments. Even though more women than men have received Ph.D. in English since 1987, the top 50 departments are predominantly male, and male faculty members publish more books than female faculty members [23].

Significant differences were found in the areas of contribution between male and female professors. Men focus more on areas related to biology and ecosystems, while women appear to be more oriented towards education and management. In the literature, no studies were found that specifically identified the areas of contribution showing significant differences between male and female professors in STEM. These disparities could be attributed to the professors' areas of specialization and the gender barriers they encounter when accessing certain research areas.

Overall, women appear more frequently as the first author compared to men, which contrasts with findings from previous studies. For instance, a bibliometric review of articles on COVID-19 published in major Spanish medical journals found that women accounted for only 36.7% of first authors and 33.7% of last authors [24]. Another study examining gender differences in authorship of original research articles in two prominent anesthesiology journals in the United States found that men were more likely to be first or senior authors than women [25]. The difference observed in the present study could be attributed to women at this university striving to advance their careers, leading to their higher frequency as first authors. It would be worth analyzing in future studies whether this trend persists or aligns with previous literature.

The reasons for the gender gap in scientific publications are complex and multifactorial. Some of the factors that contribute to this issue include gender bias, discrimination, and the higher burden of domestic duties that women face [10]. To ensure gender equality in academic publications, universities and the editorial boards of journals should fight against gender-based bias and discrimination [9, 24].

The study has several limitations. Firstly, it was conducted at a single university, which may restrict its generalizability to other higher education institutions. Secondly, the analysis timeframe of 10 years may not provide a complete picture of the professors' scientific production. Lastly, the analysis focused specifically on STEM, limiting its applicability to other disciplinary areas.

Despite these limitations, the study offers valuable insights into the scientific production of professors in the STEM field at the Technical University of Loja (UTPL). These findings can inform efforts to enhance the quality of teaching and research at the university. Moreover, they facilitate the identification of barriers faced by professors in STEM, which can aid in implementing policies and programs to overcome these challenges. The study also provides a foundation for future research in the STEM field and other academic domains, contributing to the advancement of knowledge in education and STEM research.

V. Conclusions

This study aimed to identify and analyze the gender gap in scientific publications in STEM fields, specifically within a particular university in southern Ecuador. The findings reveal a gender gap in the scientific production of university professors, with fewer women than men occupying top positions in terms of publications and citations over the past 10 years. Despite this gap, women are well-represented in the areas of education and management, while men tend to focus more on areas related to biology and ecosystems. In terms of publication types, men publish more articles in journals and books/book chapters, whereas women tend to publish more in conferences. While no significant differences were found in the relationship between the number of publications and citations between men and women, there is a noticeable trend of lower representation of women in top positions of scientific production. These results highlight the presence of gender barriers in academic productivity and access to specific research areas. Further research is crucial to gain a deeper understanding of the underlying causes and to develop effective strategies for addressing this issue.

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