Gender Diversity in STEM Graduate Programs at the University of Brasília in Brazil

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***Abstract*—Increasing gender diversity in STEM graduate programs is a challenge. In Brazil, the National Council for Scientific and Technological Development (CNPq) has classified knowledge into different "broad areas", one of which is Exact and Earth Sciences (EES). This area includes the STEM subjects: Physics, Computer Science, Mathematics, Statistics and Chemistry. These EES areas have a low representation of women. The University of Brasília, one of the top 10 universities in Brazil, has graduate programs (master's and doctoral degrees) in all these subjects. In this context, this paper has the main research question: What is the level of gender diversity in each EES area at the University of Brasília in master's and doctoral programs? This research question was analyzed with the indicators of student enrollment, number of graduations, and retention rates in the programs. The data used for analysis were the available Brazilian open public data of graduate programs for 11 years, 2007-2017. The findings include that women are in the minority in the total number of graduates in Computer Science and Physics. Despite the low number of women overall in EES, the Chemistry program stands out with the highest female participation, reaching more women than men at the doctorate level. The program that has the fewest women is Computer Science. This paper presents all the results of this study.**

***Index Terms*—Master's, Doctorate, Women, Exact Sciences**

I. Introduction

According to the Brazilian foundation *Coordination for the Improvement of Higher Education Personnel* (CAPES), in 2020, women represented 57% of master's and doctoral scholarship holders in Brazil. In 2020, women also represented 53% of enrollments (195,000 out of 364,000) in graduate programs [1]. According to Monard and Monteiro [2], in Brazil, the number of women in master's degree programs exceeded men in 1998 and at the doctorate level in 2007. However, female predominance is not seen in all areas of knowledge. Women are the majority in the areas of Health Sciences and Liberal Arts. In the areas of Exact Sciences and Earth Sciences (EES), women have a lower level of representation. CAPES establishes that EES is composed of different areas of knowledge [3]; in this paper, the analysis involves the areas of Physics, Computer Science, Mathematics, Statistics and Chemistry.

At the University of Brasília (UnB), in 2019, the number of female students in the master's and doctoral programs was greater than that of male students. However, when only the graduate programs of the Computer Science Department of this university are analyzed, the percentage of female students at the master's and doctoral levels is less than 20% in the same year [4].

The problem of female underrepresentation in graduate programs is also a reality in the United States [5]–[7], Europe [8] and Canada [9]. Regarding the reasons for having few women in STEM, the following factors stand out: low representation of women professors and instructors in academia, problems with a sense of belonging in STEM and bias against women in STEM [10]–[16].

Although it is well known that the number of women in STEM is low compared to men in the master's and doctorate, there is a lack of information in the literature in Brazil on how this difference between the genders plays out in each area of STEM. This information is important so public managers can target action in STEM areas with fewer women. The Brazilian government has encouraged projects in the area of girls in STEM but does not have a specific action plan for areas that have a greater gender gap.

In this context, this paper presents the following research question: What is gender diversity in each area of Exact and Earth Sciences (EES) at the University of Brasília in the master's and doctoral programs? The aim is to find the level of gender diversity in each area of EES, specifically, if the number of women graduating in the master's and doctorate programs is the same in the different areas of EES. Analysis of the number of new entrants, active students, certified students and students who dropped out of the programs is presented. The methodology was based on the analysis of open public

data from the Brazilian government with 11 years of data (2007-2017) from the programs in the EES area of one of the top 10 universities in Brazil.

This paper is organized as follows. Section II presents the steps carried out in this research; Section III describes the results we have found; Section IV presents a discussion, and Section V gives some conclusions and future work.

II. Methodology

The methodology used in this research (Figure 1) and was inspired by the Knowledge Discovery in Databases (KDD) process [17]:

- Data Collection: raw data download from Brazilian Open Data from CAPES;
- Data Selection: definition of the study range and metadata;
- Data Cleaning: correction of inconsistencies with the aid of programming technology;
- Data Visualization: creation of graphs for analysis and knowledge generation; and
- Data Analysis: interpretation of the generated data.

Each step mentioned above will be explained in the following subsections, except for the data analysis step, which will be covered in the Results Section.

A. Data Collection

Data collection was performed by downloading files in CSV format from the Brazilian open data platform. The files were organized into periods on the platform. The first period covers the years 2004 to 2012, and the metadata have few variations in their names. In the second, between 2013 and 2016, new metadata were included and others were excluded. Finally, there is the range between 2017 and 2020 with the most recent data.

B. Data Selection

At this stage, the analysis interval, metadata and which metadata would or would not be relevant for the present research were decided. Therefore, the files obtained were from graduate programs in UnB between 2007 and 2017 [18].

Each file referring to student information has more than three hundred thousand lines. However, as a study objective, data from the Exact Sciences of the University of Brasília were prioritized. The EES area encompasses Mathematics, Statistics, Chemistry, Physics, and Computer Science.

C. Data Cleaning

This step is responsible for removing irrelevant data and separating that which is useful. The flow consists of three sub-steps: (1) data processing, (2) metadata removal, and (3) data joining.

In the first sub-step, data processing is performed. A program was developed using the Python language and applied to remove all accents and special characters. The program considered as input a file in the CSV format, and as output generated another modified CSV file.

In the second sub-step, metadata removal, all columns (metadata) not used in the analysis were removed from the files. This deletion was done manually in the Excel tool.

For the third sub-step, data joining, a program was developed in the R language to transform the 11 files into only one with an RDS extension. This extension has the advantage of storing large volumes of data in a compressed form [19]. Instead of accessing the 11 CSV files (one for each year of the study), the access can be done only in the RDS file, passing the joins that would always be done taking into account the base year.

D. Data Visualization

The data visualization step aims to display important information graphically to facilitate their analysis. In this step, the R language was used with the packages *Shiny* and *ggplot2*. The first package, developed for software R users, is a statistical computing environment where you can create interactive applications in HTML language in a simple and intuitive way [20]. The second package, *ggplot2*, is an implementation of Leland Wilkinson's *Grammar of Graphics* ideas, where data visualization is defined as the creation of statistical plots from semantic components such as scales and layers [21]. Both packages were used to build the graphs in this paper.

III. Results

In this section, the results of the analysis of master's and doctoral data in Exact Sciences at UnB are presented. Graduate studies in Brazil are regulated by CAPES, with two years for the master's degree and four years for the doctorate. In the master's degree, it is possible to request an extra semester and in the doctorate one year. The basis of analysis was 11 years (2007-2017).

A. Master's

Figure 2 shows the number of *"freshmen"* and *"enrolled"* students per year in all master's programs. The term, *"enrolled"*, means those who had admission prior to the year being analyzed and *"freshmen"* those who were new students and had their admission in the year being analyzed. The term *freshmen*, despite being commonly used in undergraduate majors, in this paper, was used to differentiate between new and previously enrolled graduate students.

In general, in all five subject areas, for both, new entrants and previously enrolled students, the number of male students exceeds the number of female students. In Statistics, Mathematics and Chemistry, there are occasional exceptions to this. Chemistry is the subject area with the smallest gender gap. On the other hand, the difference between the numbers of men and women is most significant in Computer Science.

In Statistics, 62.39% of *freshmen* were men and 37.61% were women. Women had more admissions to the program than men in 2014 and 2016. In the last year of the study, more women enrolled students than men. In Physics, of the new entrants (*freshmen*), 72.89% were men and 27.11% were women. The Computer Science program has the biggest

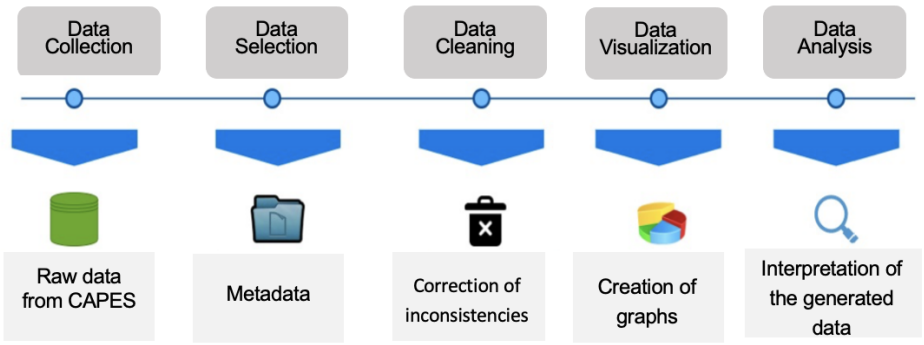

Fig. 1. Applied methodology.

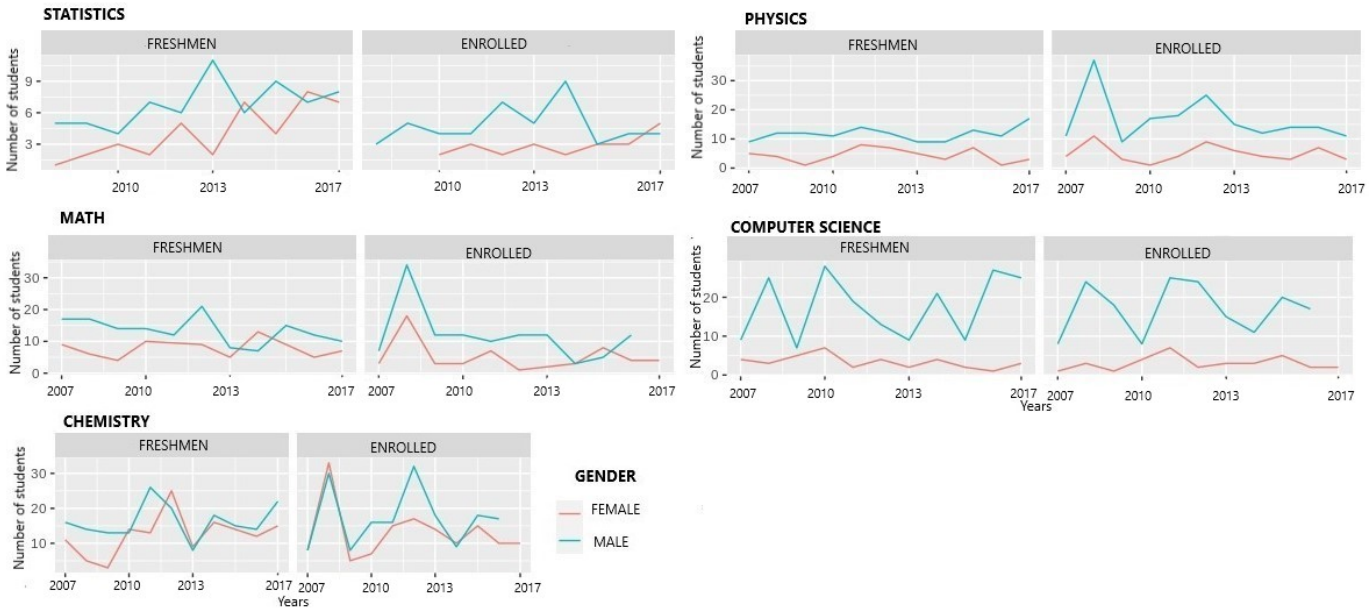

Fig. 2. Freshmen and Enrolled in the Master's Degree in EES by program from 2007 to 2017.

difference between men and women, only 14.28% of *freshmen* were women. In Mathematics women represent 34.37% of those new students at the graduate program. Chemistry is the field that has the closest percentages between men and women, although men represent the majority of *freshmen* and enrolled students. Of the new entrants, 43.35% are women.

Figure 3 presents the students who obtained a master's degree from 2007 to 2017 by major, year and gender. Despite the fact that, in specific years, the number of female students in certain programs was higher, overall, the percentage of men who graduated in the entire period was higher. The area with the highest percentage of women is Chemistry, at 46.35%, while Computer Science has the lowest percentage (14.17%). Table I presents the total numbers for each area.

In Statistics and Computer Science the number of men graduating exceeded the number of women in all 11 years. However, in Statistics, from a low base of zero in 2010, the number of women graduating had almost equaled the number of men by 2017. By contrast, there is no such decrease in the gender gap in Computer Science. This program has the largest gap between the numbers of male and female master's graduates.

TABLE I
NUMBER OF MASTER'S DEGREE STUDENTS WHO GRADUATED FROM 2007 TO 2017 BY GENDER.

Program	Men	Women
Statistics	50	25
Physics	60	31
Computer Science	115	19
Mathematics	79	38
Chemistry	103	89

Mathematics and Chemistry show different trends. In Mathematics, in 2012, 2015 and 2016, there were more female

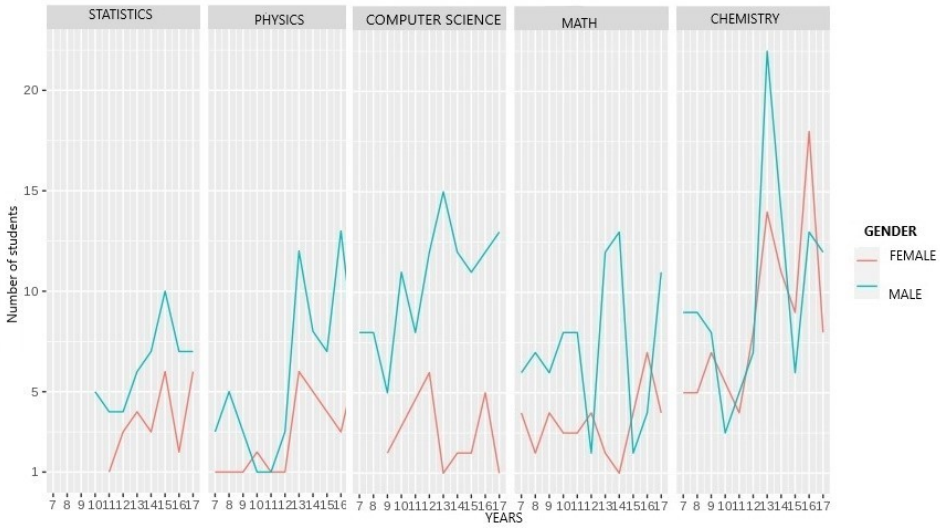

Fig. 3. Master's degree students graduated from 2007 (represented by 7) to 2017 (represented by 17) by major, year and gender.

graduates than males. In the year when most women obtained a degree (2016), they represented 63.63%. In Chemistry, even though men graduated in larger numbers, the difference between them is small. Overall, 46.35% of the graduates in this program were women.

Figure 4 shows an analysis of the number of master's graduate students using a *boxplot* chart. With this graph it is possible to observe the behavior of the distribution of each variable, as well as their variability according to the size of the box and the distance between the first and third quartiles.

In Statistics, there is a significant difference between the percentage of male and female students. Both have variations between the percentages, but this variability is greater among the percentages of men.

In Physics, the height of the women's *boxplot* is greater than that of men, which means that there is greater variability in the female percentages. Women have an *outlier* point, as in 2010 there were only female graduates.

When analyzing the Computer Science *boxplot*, the difference between the percentage of graduated doctoral students among men and women is clear. The distribution of men reaches the maximum percentage of 100%. For all years, men's doctoral percentages are above 50%. The first quartile is 88.89% and third quartile 100%. Meanwhile, the distribution of women percentages is below 50%. It is also possible to observe that the men's *boxplot* in Computer Science reaches the highest percentages of graduates when compared to all other programs under study.

In Mathematics, the *boxplot* has a large distance between the first and third quartiles. With this, there is unpredictability, where values are high, sometimes low. The distance between the quartiles of both genders is the same.

In Chemistry, note that the *boxplots* are more concentrated and both have an outlier. The fact that they are more concentrated means that there is a smaller distance between the quartiles. Here, the percentages of men and women are closer than in other programs. However, note that the third quartile of women is close to the median of men, which means that the highest percentages of women are close to the lowest percentages of men.

In general, the median of the women's boxes are close to each other, always between 25% and 50%, except for Computer Science, which is below 25%. The same happens with men; their median is between 50% and 75%, except for the Computer Science program. Statistics and Computer Science *boxplots* have the greatest difference between men and women.

In the period 2007 to 2017, most of the students who dropped out of EES programs were male (68.56% male and 31.44% female). Figure 5 shows the sum of all master's students who dropped out of the programs during the research period by subject area.

The analysis of the dropout rate by gender is different in each area. Considering the percentage between the number of students enrolled in the program and the number of students who dropped out of the program, Statistics had the worst performance for women, where there was a 39.13% dropout rate, while for men, it was 14.58%. Women had a lower dropout rate in Physics (3.63% of women and 10.38% of men) and Chemistry (9.02% of women and 19.76% of men). Men and women had similar numbers in Mathematics (51.78% of women and 49.57% of men) and Computer Science (31.03% of female students and 27.64% of men).

B. Doctorate

Figure 6 shows the number of freshmen and students enrolled by area per year. In Physics, the number of men enrolled is higher than that of women every year. 2015 had the smallest difference between men and women enrolled (29 men and 20 women). In 2013, there were more female entrants than males.

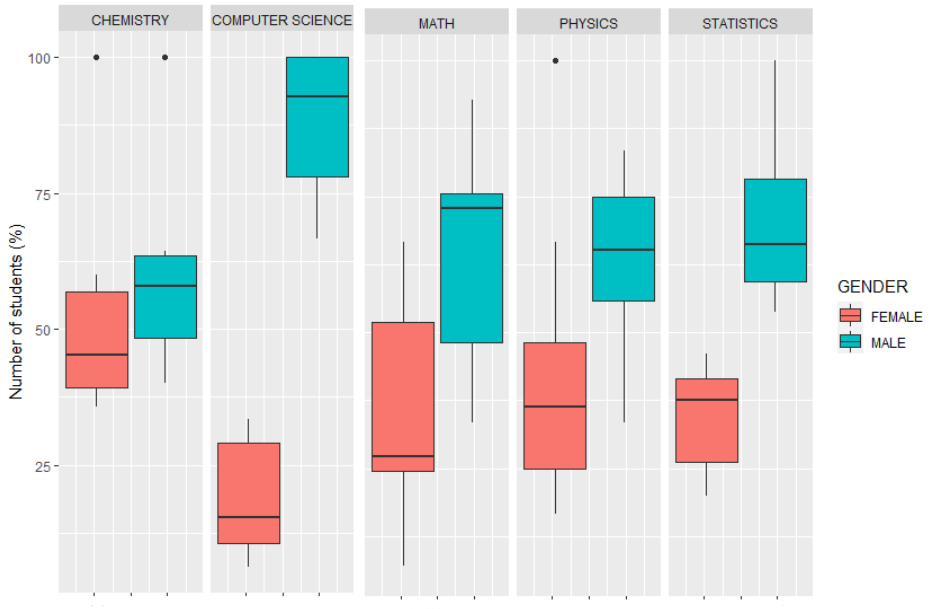

Fig. 4. Percentage of Master's degree students graduated from 2007 to 2017 by gender.

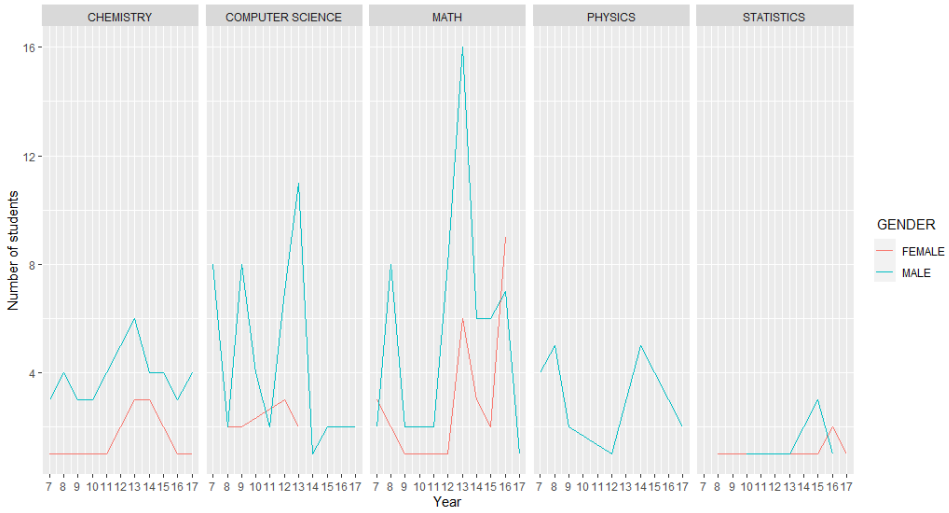

Fig. 5. Dropouts in Master from 2007 to 2017 by gender.

Computer Science is the only program in which women in both student groups do not, at any point throughout the period, equal to or exceed the number of men. Since 2011, the number of men enrolled in this program has increased. It is important to note that the largest number of women was in 2014 and 2015, with 3 students enrolled, while men were below 10 only in 2011.

In Mathematics, men are in the majority in both student groups. Despite the larger male representation, there are exceptions, see 2009 and 2011.

Chemistry is the program with the smallest gap between numbers of men and women enrolled as well as newcomers. In all the years considered, male new entrants are in the majority in only 5 of the 11 years. Furthermore, for 3 years the numbers of men and women are the same and in the remaining 3 years women are in the majority. With regard to previously enrolled students, the number of women is equal in 2007 and 2009, and exceeds that of men in 2017.

Figure 7 and Table II show the numbers of male and female PhD graduates, by area and year. Unlike the master's, there is one program in which more women than men graduated. This is Chemistry, where women accounted for 53.75% of the graduates. In other areas, female Ph.D. graduates were in the minority (Physics had 27.66%, Mathematics 28% and Computer Science 10%).

In Physics, more men graduate every year except in 2010 and 2017. In 2017, 75% of the graduates were women. It is noteworthy that the number of female graduates has been

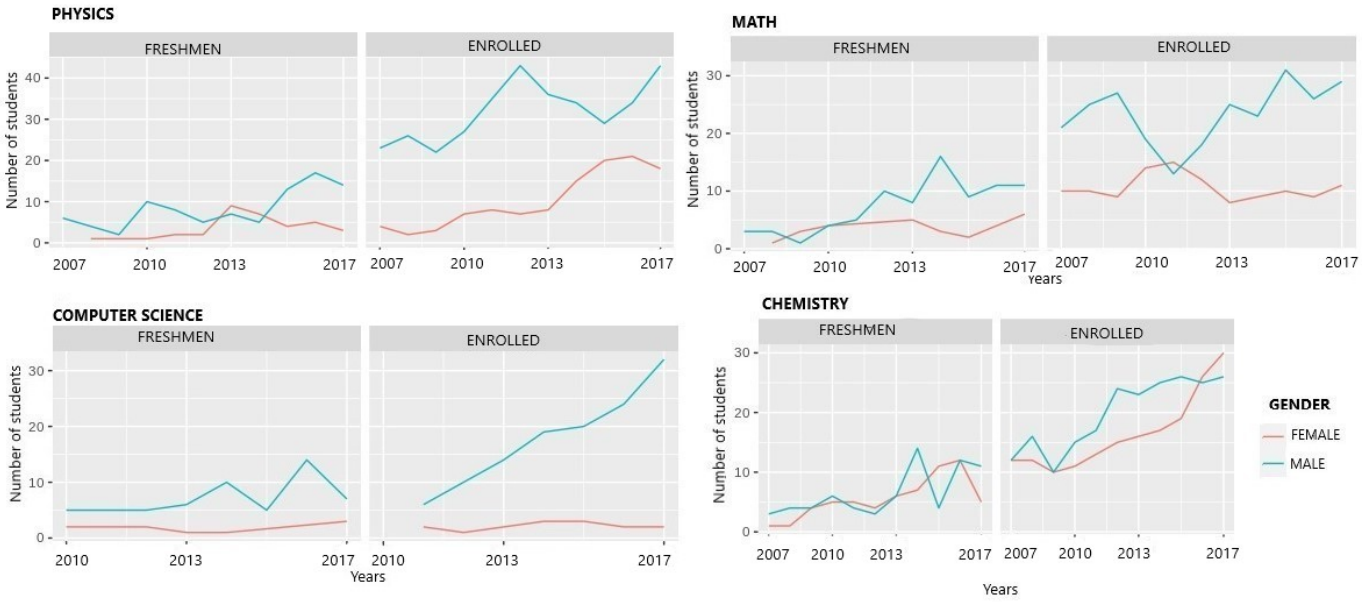

Fig. 6. Freshmen and Enrolled in the Doctorate in STEM by program from 2007 to 2017.

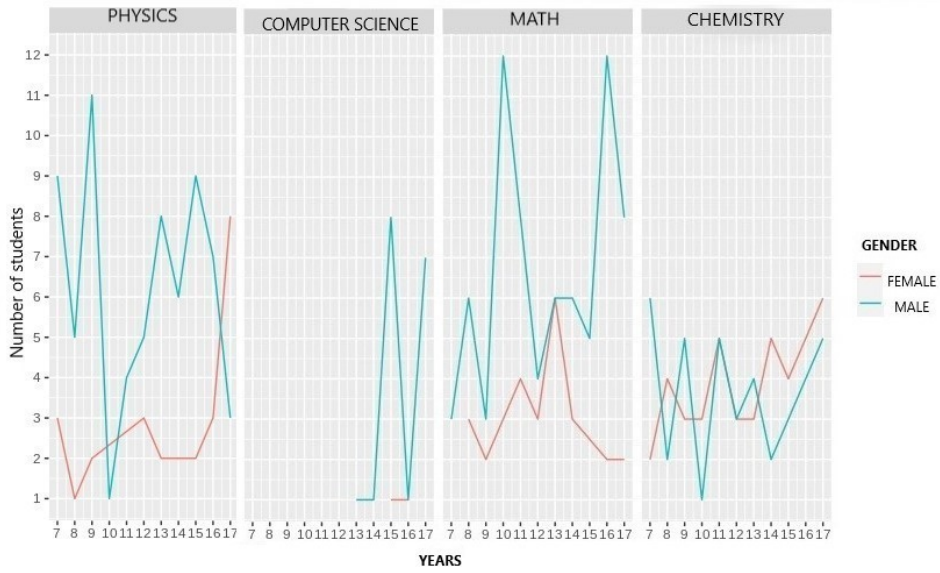

Fig. 7. Doctoral students graduated from 2007 to 2017 by major, year and gender.

TABLE II
NUMBER OF STUDENTS, BY SEX, WITH PH.D. DEGREES FROM 2007 TO 2017.

Program	Men	Women
Physics	57	37
Computing	18	2
Math	70	31
Chemistry	32	48

growing in this area since 2008.

In Mathematics, there are more male graduates in all years, except in 2013, which had the same number of men and women. The year with the biggest difference between genders is 2016, when 14.28% of graduates were women and 85.72% men.

Chemistry was the program with most women graduates compared to all the EES doctoral programs at UnB in the years of this research. This is the only program that has more women graduates than men. Here, 53.75% of the graduates, over the entire period, are women. The number of female graduates in this program is growing.

From the *boxplot* graph, Figure 8, an analysis of the data variation is performed. In the Physics Program, the *boxplots* of both genders show the smallest difference between the first

and third quartiles. The first quartile and the third quartile comprise 50% of the sample values, therefore there is a large gap between the female and male percentages. The lowest percentage of men is much higher than the highest percentage of women.

In Computer Science, the women's *boxplot* is thin because women graduated in only 2 of the 11 years considered. In this area, the median of women is 30.55%, first quartile 20.83% and third quartile 40.27%. For men, the median is 100%, first quartile 88.89% and third quartile 100%. These high percentages of graduates are present because in most years only men graduated.

In the Mathematics *boxplot*, a behavior similar to the Computer Science program is observed. For all years, women's doctoral percentages are below the 50%. More specifically, the median of women is 33.33%, first quartile 20% and third quartile 40%. For men, the median is 66.67%, first quartile 60% and third quartile 82.86%. It is also possible to observe that the highest percentage in females is equal to the lowest rate in males. That is, 100% of the percentages for men are higher than for women.

Chemistry is the only area in which the median of women is higher than that of men, demonstrating there were more female graduates than males. Note that the highest percentage of graduates in the graph is 100% because in 2015 there were no male graduates. In this area, the median of women is 54.55%, first quartile 46.42% and third quartile 69.05%. For men, the median is 47.72%, first quartile 36.10% and third quartile 55.36%. Here, the women's *boxplot* has greater variability in percentages. In this program, the lowest rate observed was the same for men and women. However, around 75% of the percentages of men in the program are below the median of women, that is, the median of women is close to the third quartile of men.

In general, the difference between men and women is extensive, with more men than women in most programs, except in Chemistry, where women graduates are in the majority. It can also be observed that more than 50% (median) of the data from women in the Chemistry program are above the percentage of 50% of students.

Turning finally to drop-out rates (see Figure 9), in Chemistry and Mathematics at the doctoral level, the highest rates are for the male students almost every year, except in Chemistry in 2013, where it is the same in both genders. In Computer Science, despite the graph showing a higher rate of female dropout, it is important to note that women dropped out only in 2013 and 2014, while men had a constant of one student per year from 2011 to 2015. In Physics, there is a steady decrease in the number of women dropping out, while the data for men fluctuates over the years.

IV. Discussion

In general, women are less represented in all areas of EES when considering graduate students at the master's and doctoral levels, at the UnB, and in Brazil in general, as presented in [22]. However, gender diversity in EES areas varies widely. The Chemistry program, at the doctoral level, in 2016 had more women than men. The Computer Science and Physics programs had the lowest female representation. At the master's level approximately 42.56% of the Mathematics and Statistics students were female.

In the master's degree, in general, the most significant number of women is concentrated in Chemistry, and the smallest number is in the areas of Physics and Computer Science. In the doctorate, the largest female representation is in Chemistry and the smallest in the areas of Computer Science and Physics.

The area of Computer Science, both in the master's and the doctorate, has the lowest female representation in graduate studies at EES. While in other EES areas, the number of women increased between 2007 and 2017, in the master's and doctoral programs, in the area of Computer Science, the number of women remained stable at an average of 3 students in the master's and 6 students in the doctorate. However, the number of vacancies in the master's program more than doubled during the analysis period (2007-2017). In the doctoral program, it more than quadrupled, which further increased the challenge of diversity in graduate programs in Computer Science. Our results for Computer Science are similar to those in the United States, as presented by Trapani and Hale [23] in Higher Education in Science and Engineering, in which a little over 20% of Ph.D. graduates in Computer Science were women, the area with the fewest female PhDs in the report.

In the higher education pipeline, having few female students in graduate programs can result in fewer female faculty members. Studies report that having female faculty members encourages female students to select a similar major; that is, role models could play a part when choosing a university major [24].

V. Conclusion

This paper presented an analysis of newcomers, enrolled and graduates in the Exact Sciences programs at UnB at the master's and doctoral levels.

In general, men are in the majority at both levels. When the programs and levels are analyzed in detail, it is confirmed that the number of men entering, enrolling in and graduating from EES is higher than that of women.

Despite the general low female representation, gender diversity in EES majors varies greatly. Chemistry at the doctoral level had more women than men, while Computer Science had the lowest female representation in the master's and doctorate.

Women scientists in the field of STEM is critical to increasing diversity in this field. The data presented in this paper show that areas such as Chemistry have already managed to achieve gender diversity, but areas such as Computer Science in the 11 years analyzed still have a significant diversity problem. Having few computer scientists presents many problems, such as the lack of representation, where computer students do not have female models to look up to.

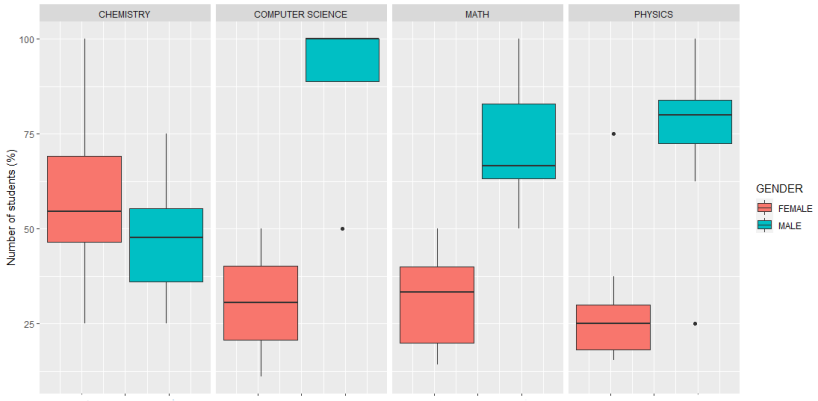

Fig. 8. Percentage of doctoral students graduated from 2007 to 2017 by gender.

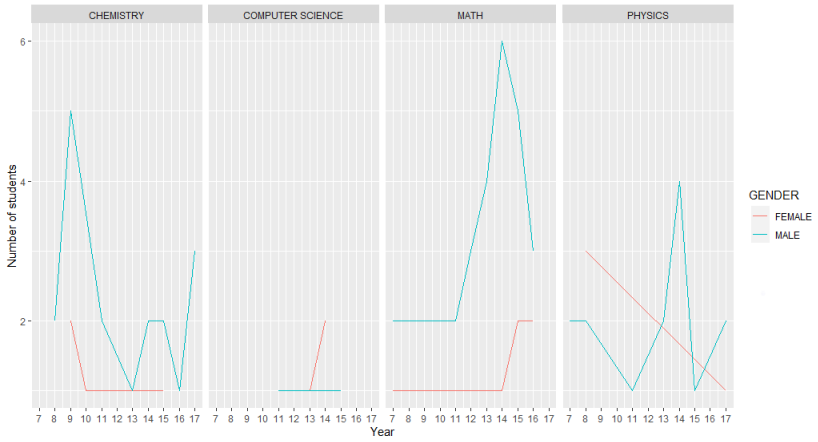

Fig. 9. Dropouts in Doctoral degrees from 2007 to 2017 by gender.

Another important point is the creation of public policies with incentives, such as specific projects for women in areas with fewer women. The Brazilian government has created funding for women in STEM, but the areas within STEM are not analyzed in the distribution of these resources.

For future work, it is intended to extend this study to all universities in Brazil using the open public data of CAPES. From these data, we intend to analyze the faculty demographics of the programs and make predictions about female representation in the master's and doctoral degrees.

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