IOSR Journal Of Humanities And Social Science (IOSR-JHSS)
Volume 29, Issue 3, Series 5 (March, 2024) 48-52
e-ISSN: 2279-0837, p-ISSN: 2279-0845.
www.iosrjournals.org

The Influence Of Gender In Undergraduate Courses: The Case Of Uece Physics Program

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Abstract:
Background*: This text examines the gender disparity in the field of physics, highlighting historical challenges faced by female scientists. It notes the predominant association of male figures with physics, while female contributions are often minimized or erased. The feminist struggle for gender equality in scientific research is discussed, emphasizing the disproportion of women in exact sciences and engineering. The study conducted at the State University of Ceará focuses on the underrepresentation of women in an Undergraduate Physics Program, exploring admission and success rates. The text underscores some of the broader implications of gender disparities in hindering human progress, aligning with the United Nations' Sustainable Development Goal of gender equality and women's empowerment.*
Materials and Methods*: This study is centered on the Undergraduate Physics Program (UPP) of Ceará State university (UECE), which was established in 1998 to address the demand for physics teachers in basic education. Data from all students enrolled in the UPP from 1998 to 2022 were utilized to analyze the association between academic success, or failure, and gender, considering only binary gender variables due to data limitations. The chi-squared significance test was applied, with a rejection criterion of a p-value less than 0.05. The study aims to contribute insights into gender-related issues within the field of physics, particularly in the context of the UPP at Ceará State University (UPP-UECE).*
Results*: Statistical analysis revealed a significant gender asymmetry in enrollment numbers. Out of a total of 3,430 students, 81% are male, while only 19% are female. The success rate in the program is notably low, with only 19% of those who left the program considered successful graduates. However, despite the male-dominated nature of UPP-UECE, the statistical analysis does not support the existence of better academic success rates for male students. The chi-square test results in a p-value of 0.45, indicating no significant correlation between gender and academic success. In other words, academic success in the UPP appears unaffected by gender, challenging the assumption of male privilege within the analyzed dataset. This finding suggests that while there is a gender disparity in enrollment, other factors beyond academic success may contribute to gender imbalances within the course. Further examination is needed to understand the nuanced aspects influencing the observed gender patterns in UPP-UECE.*
Conclusion: *This study highlights the high rate of academic failure in the UPP, exceeding 80%, attributed to factors like inadequate basic education, insufficient professional planning, and socio-economic difficulties. Understanding and addressing these challenges are crucial for creating a more supportive and inclusive academic environment. The need for a nuanced exploration of factors influencing gender dynamics within the course is explored, recommending qualitative research for deeper insights. Measures such as raising awareness, implementing anti-sexism measures, offering gender-related courses, and establishing mentorship programs for women are proposed to combat gender discrimination and foster inclusivity. A more nuanced understanding is deemed essential for effective strategies to promote gender equity in this academic environment.*
Key Word*: Gender Disparity; Gender Asymmetry; Exact Sciences; Undergraduate Physics Program*

Date of Submission: 04-03-2024 Date of Acceptance: 14-03-2024

I. Introduction

Physics is an area of knowledge with enormous potential to change the way society relates to nature. Because of this, prominent figures become recognized worldwide for their contributions. Isaac Newton and Albert Einstein, for example, are names very frequently associated with science and research in this field; female names, however, are not as closely linked to it in people's minds. It is clear that in this field, there is a majority of male researchers both in number and in recognition (SCHIEBINGER, 2008).

This probably happens because female contributions to these areas are often minimized or even completely erased. For instance, Amalie Emmy Noether, a German mathematician and physicist who formulated Noether's theorem – a theorem that highlights the correspondence between symmetries and conservation laws – faced difficulties, such as studying in the back rooms of the university without receiving proper academic credit for over two years until she was admitted as a student. During that time in Germany, not so long ago, women were prohibited from higher education (IGNOTOFSKY, 2017).

In the present days, the feminist struggle to enter positions of power has raised questions about how society is structured regarding gender issues in various social fields and, specifically, in the institutional realms of scientific research (HIRATA, et al, 2009). There is often a disproportion in the number of women compared to men in scientific fields, especially in the areas of exact sciences and engineering. This pattern is present in many countries, as pointed out by Cunha (2020).

In the professional realm, this issue can be associated with traditional conceptions that assign women the fundamental roles of motherhood and household tasks, while men are seen as the providers for the family (DE BEAUVOIR, 1949). As a consequence, the absence of women in intellectual circles has become common. A study conducted by the Brazilian Academy of Sciences (ABC, acronym from Portuguese "Academia Brasileira de Ciências") found that the number of women is very small in all of the institution's areas of research, with a maximum of 25% in the fields where they are more frequent (biological sciences) and a minimum of only 1% in engineering. Additionally, the study revealed that the concentration of men increases as one advances in the scientific career (FERRARI et al, 2018).

This situation is so concerning that the United Nations has chosen gender equality and women's empowerment as the 5th Sustainable Development Goal (SDG). SDGs aim, in general, to promote actions to address global issues such as poverty mitigation, environmental and climate protection, among others, to ensure that people everywhere can enjoy peace and prosperity (GOMES & FERREIRA, 2018). Thus, it can be strongly argued that the problems of lack of female representation and of deficiencies in recognizing female achievements are widely accepted as flaws that hinder, or even impede, human progress on a global scale.

In this context, this work aimed to address the issue of the absence of women in the exact sciences, discussing some of the difficulties women face when pursuing an undergraduate degree in these areas of knowledge. To highlight this phenomenon, a survey was conducted on admission and success rates, related to gender, in an Undergraduate Physics Program (UPP) at the State University of Ceará (UECE, acronym from Portuguese "Universidade Estadual do Ceará).

II. Women In Science

To use gender as a descriptive category implies using "gender" as a substitute for "sex" to prevent reducing discussions about gender inequalities to biological or sexual differences. This interpretation is considered reasonable in face of the extensive dialogue that is already taking place around sex differences and the perceived "innate deficiencies" of women in analytical, mathematical, and scientific thinking. However, it has to be noted that blurring the distinction between "sex" as biological characteristics and "gender" as a social construct may contribute to perpetuating gender prejudice against women (MORGENROTH; RYAN, 2020). By maintaining a nuanced understanding of both biological and social aspects, discussions can be more effective.

As such, in certain areas of scientific research, it can be argued that there is a discriminatory paradigm . According to authors Fehrs and Czujko (1992), the basic premise for this is deliberate exclusion, even if unintentional, by society and the scientific community itself, which is stronger in the exact sciences such as physics. According to the authors, this exclusion occurs due to the unfair treatment of women.

Women's interest in the fields of exact sciences, technology, and mathematics is most often discouraged, while inclination towards other areas socially accepted as feminine (based on roles and behaviors considered suitable or unsuitable for women), such as the fields of humanities and health, is much more commonly encouraged. However, there is no scientific evidence supporting such separation (CANTA; PANTOJA, 2019; RODRÍGUEZ-SIERRA, 2016).

An iconic example of this phenomenon is the trajectory of Lise Meitner, a physicist born in 19th century Austria, whose achievements set a milestone in the field of nuclear physics. She contributed to the discovery of the nuclear fission mechanism, and to the synthesis of a stable isotope of the element protactinium. However, despite her brilliance in her field, being a woman deprived her of using the laboratories and even the bathrooms where she worked, at the Institute of Chemistry in Berlin (IGNOTOFSKY, 2017). What happened to her – and,

of course, many other women – shows that sexism remains ingrained in institutions, even academic ones, as pointed out by Barros and Mourão (2020) when stating that the presence of women in universities was undesirable until the early 20th century.

Other problems also stem from the concept of human nature, which is often linked to the social Darwinism hypothesis (although never defended by Darwin but by Herbert Spencer) (MEAD, 2015). Social Darwinism asserts that certain human groups are naturally more apt for certain functions, activities, or positions of power. This has been identified by many contemporary scholars as another attempt to naturalize structures of domination by certain groups over others, perpetuating inequalities, such as predatory capitalism, patriarchy, racism, etc. However, arguments based on the idea that the lower proportions of women in certain sectors of society (such as political spaces or areas of exact sciences) are justified by biological factors typical of the female gender are still commonly propagated. This often makes women less interested – and capable – of making real contributions in such sectors, contributing to perpetuating the problem (GONZATTI et al, 2020).

Simone de Beauvoir is an important author who, noticing the discrepancies in gender roles legitimized by biological justifications, already in 1949 asserted that women were "The Second Sex" (the title of the book in which she exposes these ideas), i.e., "the others", defined only by the relationships they have with men (BEAUVOIR, 2016). Now, if political and intellectual spaces – which are fundamentally power spaces – in a society are predominantly managed by male actors, there is a tendency for the maintenance of this gender-privileged structure in society, promoting subordination of female roles in these spaces (HILL; CORBETT; ANDRESSE ST-ROSE, 2010). Political or intellectual fields managed by men allow for the perpetuation of this distinction and perpetuate female subjugation because they end up accepting certain situations as natural or unfixable just to be able to reach these spaces. This may explain why few women feel comfortable in such sectors (CARVALHO, 2021).

Although (really outdated) biological justifications for this phenomena still persist, it is worth noting that anthropological studies on gender have concluded that the main factor contributing to the determination of human behavior is not biological but socio-cultural. For example, there are cultures in Guinea-Bissau where men have characteristics considered feminine in Western standards, while the opposite is observed in women. This demonstrates how human behavior is malleable by the culture imposed by a given society (MEAD, 2015).

Specifically in the field of Science, Technology, Engineering, and Mathematics (STEM fields), a minority of women has long been observed. As pointed out by Keune et al. (2019), there have recently been significant global efforts in the form of public policies or private initiatives to change this situation. However, these efforts have not proven effective in Brazil, as Fernandes (2021) points out that only 24% of workers in STEM areas are women – a contrasting number with the 47% female presence in the overall job market. In scientific research, Lima, Braga, and Tavares (2015), who compared the presence of women among CNPq (acronym in Portuguese of "Conselho Nacional de Desenvolvimento Científico e Tecnológico" – National Council for Scientific and Technological Development –, a Brazilian governmental agency) productivity scholarship recipients, indicate that the proportion of women is above 60% in health and humanities areas, while in exact sciences areas, the number drops to 30%.

Even if they do enter male-dominated fields, women often face hostile climates or lack of receptiveness when attempting to socialize with colleagues and professors. The persistence of the masculine image of a physicist leads women to be viewed as inadequate, subject to constant questioning, target to confrontations and evaluations, both academically and socially, throughout the course (BARTHELEMY; MCCORMICK; HENDERSON, 2016).

On a broader, historical, perspective, this is probably a result of limited awareness regarding female contributions to science. It is observed that young girls are more encouraged when there is representation of women who have made significant achievements in science, making them visible and integral to technological progress. Therefore the study of the lives of prominent scientists is considered a strategy to showcase their contributions. This can lead to a teaching approach based on examining historical contributions from women's history in the science movement (VIDOR et al., 2020; SCHIEBINGER, 1987).

It is not so simple, however, to achieve true equality. For example, in their work, Doucette and Singh (2024) present key ideas regarding gender equity in physics laboratories. They argue that different curricula have varying impacts on genders and, as such, gender equity depends strongly on institutional factors. Educational levels also play a role on the issue, since it is evident that a strategy that improves equity in one setting may not be ideal for another. These authors say that in the context of physics laboratories the division of tasks among students appears to be a promising strategy, when the supervisor promotes interaction among diverse participants and smooth coordination considering how tasks are assigned and the overall environment. This study emphasizes the need for continuous and applied research, aiming to progressively reduce gender inequality.

III. Methodological Procedures

In order to understand some aspects of gender social relations in the field of Physics, an exploratory bibliographic research on the topic was initially conducted to theoretically ground the research and obtain a few

key concepts and results already observed in other works (SOUSA; OLIVEIRA, and ALVES, 2021). Thus, books, articles, and other types of academic production relevant to the theme and the phenomenon under study – the gender asymmetry observed in the fields of exact sciences and, particularly, in physics – were consulted through searches on the Scielo and Google Scholar electronic repositories.

The focus of this study was Ceará State University's Undergraduate Course in Physics. This program was created in 1998, in the city of Fortaleza, as a continuation to the then extinct Short Undergraduate Course in Sciences (Major in Physics) from the same University, which ended due to changes in the educational law. The program was created with the main objective of meeting the demand for physics teachers in basic education schools. Nowadays, the UPP exists in two modalities, each with different goals for the graduate: teaching degree (that can be taken in the afternoon or evening) and bachelor's degree modalities (taken in daytime only).

Data on the academic situation of all students ever enrolled in the UPP, since its beginning in 1998 and until the end of 2022, at the State University of Ceará was used for the construction of the quantitative phase of this work. This data was obtained from the coordinators of the mentioned program with the approval of the University's Department of Studies and Graduation, the ultimate holder of this data.

The academic situation is defined by a code indicating the student's situation as in progress (considered a neutral situation and ignored in the course success study); abandonment, deactivated, transferred, withdrawal, detached, canceled, and detached "ex-officio" (all considered unsuccessful situations in the course); graduated and completed (both considered successful situations in the course).

Contingency tables that relate success-failure numbers as (binary) dependent variables of the (again binary) gender variable were constructed. In this study, the multiplicity of other genders (for example, transgender and non-binary populations) was disregarded since this situation is not reported in the official institution's data. Moreover, it is considered that the (thought to be small) number of students in this situation do not affect the statistical significance of the results. The contingency tables were then subjected to the chi-squared significance test, which allows pointing out the association between categorical variables (AGRESTI, 2014). The criterion for rejecting the null hypothesis was a p-value of less than 0.05.

IV. Results

The results obtained through statistical analysis reveal significant patterns related to gender asymmetry in the Undergraduate Physics Program (UPP) at the State University of Ceará. Below are the main findings and some discussions about their implications.

The contingent of students in UECE's UPP is presented in Table 1, according to classifications into groups based on academic status (success, in progress, or failure) and gender (male or female). From Table 1, it is evident that out of a total of 3,430 students, the UPP alumni predominantly consists of male students, with 2,876 individuals, which represents 81% of the total. In contrast, only 554 are female, or 19% of the total. Thus, it can be concluded that the UPP is a predominantly male social space.

Furthermore, it is shown that the program's success rate is alarmingly low. Among those who have left the program, only 19% are considered successful, meaning they have graduated with a degree.

Table 1 - Number of students for each group studied.

Gender	**Male**	**Female**	
Situation			**Total**
In progress	230	56	286
Successful	495	86	581
Unsuccessful	2,151	412	2.563
Total	2,876	554	3,430

Source: the authors.

Nevertheless, although it is shown that the UPP is male-dominated, it is not possible to highlight a situation of male privilege in the course based on academic success rates. The chi-square test indicates a value of $\chi^2 = 0.58$, corresponding to a p-value of $p = 0.45$, which does not allow rejecting the null hypothesis of no correlation between gender and academic success rate. In other words, academic success in the UPP is not influenced by gender, which implies that there is no clear evidence of male privilege regarding academic success within the analyzed dataset.

While there may be a gender disparity in enrollment, the lack of a statistically significant correlation between gender and academic success challenges the assumption of male privilege in this context. It has to be said that this result prompts a closer examination of factors contributing to gender imbalances within the course, beyond the academic success metric.

V. Conclusions

To suggest that women are naturally less inclined towards the fields of exact sciences is still very common. Many reasons contribute to this discourse, including the perpetuation of privileges or traditional ideologies. This study, based on academic data from students in the UPP at the State University of Ceará, has pointed out several factors that contribute to this discourse.

This research revealed a significant majority of male students in the program, exceeding 80%. This underscores the predominantly male population of this academic space, which, in turn, imposes challenges for women entering it. Surprisingly, this gender imbalance does not seem to influence academic success rates, as no statistically significant correlation was found between gender and academic success. It is even possible to speculate that women exhibit better efficiency in the studied program, maintaining success rates equivalent to men despite facing greater challenges.

Social factors, such as implicit and explicit influences from family and school, play a crucial role in steering girls away from careers in STEM fields. The lack of encouragement in mathematics and lower expectations from teachers regarding girls' performance contribute to the construction of a perceived incompetence in these traditionally male-dominated areas. This results in low self-esteem, self-confidence, and self-efficacy, leading women to self-exclude from these non-traditional careers. For instance, the UECE Physics Program, despite training high school teachers, does not address gender issues in its curriculum. This perpetuates the scarcity of women in these fields and exacerbates gender inequalities in both academic and professional settings.

In conclusion, it is crucial to highlight the observed high rate of academic failure in the UPP, exceeding 80%. This is likely a result of various factors, including inadequate basic education, insufficient professional planning, and socio-economic difficulties. These challenges may disproportionately affect fields of study that are not as highly valued in the job market, such as scientific research and teaching, both of which are central to the education provided by the UPP. Understanding and addressing these factors is essential for creating a more supportive and inclusive academic environment, fostering success for all students, regardless of gender.

These findings suggest the need for a more nuanced exploration of the factors influencing gender dynamics within the course. Qualitative research, including interviews and surveys, could provide deeper insights into students' experiences, potential biases, and institutional factors that may contribute to the observed gender distribution. Simply raising awareness and anti-sexism Measures may be good measures to combat gender discrimination, ensuring an inclusive and respectful atmosphere. Gender-related courses that bring to light successful women scientists can contribute to reflection and the deconstruction of gender stereotypes, fostering discussions on diversity and equality. Even establishing mentorship programs for women, providing guidance, emotional support, and opportunities for professional development can be positive actions. Nevertheless, a more nuanced understanding is crucial for implementing effective strategies to promote gender equity and inclusivity in this academic environment.

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