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Examining the Influence of Gender Equity Initiatives on STEM Student Demographics

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Abstract*– Globally, men continue to outnumber women three-to-one in Science, Technology, Engineering and Mathematics (STEM), a trend evident in much of Latin America, including Mexico. Over the past decade, numerous global initiatives have sought to raise awareness about the gender gap in STEM fields and foster the active participation and development of women. Tecnologico de Monterrey, with a particular focus on the School of Engineering and Sciences, has committed to advancing gender equity. The different initiatives undertaken are presented in chronological order, outlining the institution´s journey in this regard. The objective of this work is to explore the influence of the multiple gender equity initiatives implemented in recent years at our institution on the demographics of STEM students. The study includes both freshmen and graduates from the 18 university programs offered by the School of Engineering and Sciences over the past four years. While the results may not fully meet expectations in terms of achieving proportional representation for women, this work shows that significant progress has been made in cultivating an institutional culture of equity and inclusion. Each individual effort contributes to this transformation and encourages reflection on a personal level, fostering a sense of responsibility to become ambassadors for women´s empowerment. These efforts should continue, further strengthening and inclusive culture within the university and extending their influence to the broader community. This collective commitment is essential for achieving gender equality in STEM fields.

Keywords*—Higher Education, Educational Innovation, Women in STEM, Gender Equity, Gender Equality, Engineering Education

I. Introduction

Higher education institutions in Mexico still face a crucial challenge: gender equity. Inequality in access to education has marked history, from the struggle for women's income in the 19th century to the persistent disparities today [1]. Addressing this problem requires gender awareness, including in education.

In Mexico, public and private institutions offer bachelor's degrees and engineering degrees. However, engineering and technology continue to be considered male fields despite increased female participation during the last decade [2].

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Women have managed to break barriers to access higher education, gradually eradicating exclusion [3]. However, to reach generations truly aware of equality, equity, and gender participation, inclusive education is presented as a fundamental tool.

Teaching girls and boys to live together from childhood allows them to build a solid foundation for social integration. Values such as respect, tolerance, empathy, solidarity, and the common good are fundamental to this process.

Implementing inclusive education without limitations in the short term and throughout the training process makes its application more flexible and expands its field of action. This benefits all educational levels and society.

Globally, men outnumber women three-to-one in Science, Technology, Engineering, and Mathematics (STEM). Women comprise just 35% of all students enrolled in a STEM field at the university level. The gender disparity in these fields severely restricts innovation and the bringing forth of specific perspectives to address contemporary or future challenges. Latin America and the Caribbean are two of the few places where the ratio of male and female researchers is on par: 45 % for female researchers [4]. However, women remain sparsely concentrated in the upper echelons of the established professional hierarchy.

With the advancement of science and technology, the need to provide good schooling and lifelong learning opportunities for girls and women has been emphasized by both the Beijing Platform for Action and Sustainable Development Goals. By Mexico's count, the 2020 figure reads 45 women enrolled in engineering and construction-related courses for every 100 men doing likewise. Regarding computer-related occupations, there were only 31 females out of every 100 students enrolled, thanks in part to greater attention paid to males than females. Moreover, the number of women in Mexico's National Researchers system is only 61.5 for every hundred men [5].

According to María Noel Vaeza, Regional Director of UN Women for the Americas and the Caribbean: "the factors leading to unequal outcomes for men and women in STEM are complex and varied and, therefore, are not easy to address, and some may be more influential at one stage of life than another." [5]. This gender gap may originate from childhood, both in the school environment and at home, and extends throughout professional life in areas such as research, career development, and access to jobs in these sectors. Despite women representing more than 50% of the population in Mexico, only a fraction is

dedicated to science. The Mexican Institute for Competitiveness (IMCO) points out that female representation in universities has grown notably in the last four decades, moving from 27% in 1977 to 52% in 2020 [5]. Moreover, the percentage of women who complete their university studies is higher than that of men, further increasing their proportion in the population with higher education.

Equity and quality in higher education for women is a matter of global interest. Research indicates that various countries have implemented public policies to improve academic retention and employability of women after university [6], although not always with the expected results. Despite efforts to facilitate access, there has been a noted lack of support measures throughout the educational trajectory [7]. In Europe, significant initiatives have been promoted to improve women's university education, with policies since 1995 aimed at increasing the academic retention of women in university [8], including entry quotas and incentive systems for their permanence. These policies have been implemented in countries such as Germany, Austria, and Poland [9].

However, the existence of public policies regarding the entry and permanence of women in university can imply a false discourse of equality. In the United Kingdom, although opportunities have been created for women to access university education a study carried out by McTavish and Miller indicates that 80% of higher education institutions do not have established any regulations for its implementation regarding the issue of gender differences and equality policies [10]. In Spain, patriarchal stereotypes that are reflected in masculinized engineering careers continue to be replicated, despite the efforts that have been made to increase the entry and permanence of women in STEM careers [8].

In Latin America, sociocultural factors play a significant role in the persistence of gender disparity in university education. Despite efforts to improve access and permanence, women continue to be underrepresented in careers such as engineering [11]. It has been observed that social stereotypes and prejudices limit the choice of engineering careers by female students, and that machismo, discrimination, and harassment are reasons why women do not choose engineering careers [12]. This is also related to differences in students' self-concept, especially in confidence in their abilities, interest, and motivation for the area, their experiences in secondary education, or the level of exposure to engineering before university [11], [7]. These factors are crucial for women's persistence in engineering careers, as self-concept is closely linked to their motivation and academic achievements.

II. Method

This study aims to investigate the influence of a variety of institutional gender equity initiatives implemented in recent years on the demographics of STEM students. The work includes two main phases:

1. Analysis and description of the gender equity initiatives from the past decade.
2. STEM demographics analysis from a gender perspective, considering both freshmen and graduates from the 18 engineering programs offered at Tecnologico de Monterrey over the past four years.

Tecnologico de Monterrey is committed to advancing gender equity and has had an active participation with specific actions to tackle the gender gap. Regarding the School of Engineering and Sciences, the initial diagnostic showed a bigger gender gap when compared with other schools, both in students and faculty, and even more in leadership positions [13]. This study systematically examined various institutional initiatives, synthesizing the information into a timeline to illustrate the initial deployment dates of these efforts.

All these efforts have in mind increasing women participation in higher education. Some of them focus on engaging young women in STEM careers. This work analyses the women representation in the 18 engineering programs nationwide over the past four years, considering both freshmen and graduates. The 18 undergraduate programs from the School of Engineering and Sciences are:

1. Agricultural Biosystems Engineering (BAG)
2. Food Engineering (BFE)
3. Biotechnology Engineering (BBE)
4. Civil Engineering (BC)
5. Data Science and Mathematics Engineering (BDM)
6. Sustainable Development Engineering (BSD)
7. Electronics Engineering (BEC)
8. Engineering Physics (BEP)
9. Innovation and Development Engineering (BID)
10. Industrial and Systems Engineering (BIE)
11. Mechanical Engineering (BM)
12. Biomedical Engineering (BBM)
13. Mechatronics Engineering (BME)
14. Nanotechnology Engineering (BNE)
15. Chemical Engineering (BCI)
16. Robotics and Digital Systems Engineering (BRD)
17. Computer Science and Technology Engineering (BCT)
18. Business and Digital Transformation Engineering (BDT)

For the years for which data is being analyzed, engineering students have been enrolled in 26 different campuses nationwide. The total undergraduate students population of the School of Engineering and Sciences is approximately 20,000 students. It is important to note that not all the programs are offered on every campus. The programs with higher enrollment include Industrial and Systems Engineering, Mechatronics Engineering, and Computer Science and Technology Engineering.

III. INITIATIVES

One of the first efforts of our university, Tecnologico de Monterrey, to recognize and make visible women trajectory, contributions and talent is the Mujer Tec (Tec Woman) award [14]. Initiated in 2013 by prof. Luz María Velázquez, this annual award continues to recognize outstanding women in gender issues, sciences, sports, entrepreneurship, art and culture, health and well-being, and citizenship.

One of the core values of Tecnologico de Monterrey is human flourishing, placing individuals at the center of their comprehensive development, fostering an adequate environment for their growth, well-being, and reaching their potential. This approach aims for each person to become the best version of themselves. In this context, the university established in 2017 the Center for Human Dignity Recognition to become a safer, more equitable, diverse, and inclusive institution, promoting human flourishing [1].

In 2018, the IMPULSA Network was formed in our institution as an effort coordinated by the Center for Human Dignity Recognition [16]. The IMPULSA Network was created to generate and work on proposals oriented towards gender equality, increasing women representation in leadership positions within the university, and strengthening talent attraction, development, and retention processes.

In 2019, our university joined the UN´s movement for gender equality, HeForShe. Our institution made 9 institutional-level commitments aimed at promoting gender equality, encouraging women´s participation and preventing violence against women. The 9 commitments are [17]:

1. Development of the Gender Equality Plan for the university.
2. Implementation of service points on campuses for the prevention and addressing gender-based violence.
3. Strengthening and continuous improvement of the National Gender-Based Violence Protocol.
4. Gender equality and violence prevention training for the entire university community.
5. Promotion of a culture of equal opportunities in all processes essential for the development and advancement of women.
6. Development of women in Science, Technology, Engineering, and Mathematics careers.
7. Increase the number of student groups promoting a culture of equality and violence prevention.
8. Promote academic contributions on gender issues.
9. Develop a working group in an international consortium on gender equality in universities.

Within the framework of HeForShe, the national dean of the School of Engineering and Sciences committed to work on commitment 6: Development of women in STEM careers. Therefore, in that same year, the dean invited a group of female professors to create and collaborate in a national women's network within the School of Engineering and Sciences to pursue this objective. This is how MIC (Mujeres en Ingeniería y Ciencias – Women in Engineering and Sciences), now Ingenia Women in Engineering and Sciences, emerged. Ingenia is a group of professors and collaborators committed to promoting the participation and development of women in relevant initiatives of the school. Ingenia also works with high school and undergraduate female students to promote and retain vocations in STEM careers, connect them with women role models, and promote their personal and professional development. Ingenia has presence in the different campuses along the country and is organized in five active committees: rector, mentoring, communication, liaison, and She-STEM chair for research.

In 2020, the Gender Equality Plan was presented at our university. Its purpose is to fill the community with political content and concrete actions to promote equal opportunities among all the people who make up our community. As a first step to build the Gender Equality Plan, a diagnostic of the gender gap in our university was carried out in the summer of 2020. This diagnostic included men and women who are part of the community student body in the various schools, careers, campuses, and regions and members of the community of collaborators, faculty, research groups, and management teams. It considered different indicators such as women representation in the different schools (considering students, faculty, and employees), salaries, women in leadership positions, academic production, among others. The plan has four pillars: 1) Policies and guidelines in favor of gender equality, 2) Leadership and women development, 3) Training and research on gender issues, and 4) Eradication of gender-based violence and discrimination. [13]

Additionally to these institutional efforts, women faculty from the School of Engineering and Sciences engaged with international networks that have the common objective of fostering women participation and empowerment in engineering and sciences fields. Some examples of these networks are: Matilda Latin American Chair of Women in Engineering, founded in 2020 (https://catedramatilda.org/), W-STEM Project (2020) funded by the Erasmus+ Programme of the European Union (https://course.wstemproject.eu/), and the OWSD (Organization for Women in Science for the Developing World) National Chapter in Mexico, established in 2021 (https://owsd.net/network/mexico).

Another important effort towards an environment of equality and respect are the Guidelines for Inclusive Language published by the Center for Human Dignity Recognition in 2022. Our institution promotes an environment of respect for human dignity, inclusion, and sense of belonging. These guidelines are suggestions for the wording and expressions used to communicate to avoid unconscious bias, prejudices, or discrimination. These recommendations invite people to reflect and question the traditional ways of expression and move towards more inclusive ways contributing to a more empathic and inclusive community. [18]

Fig. 1 illustrates a timeline of the gender equality institutional initiatives described.

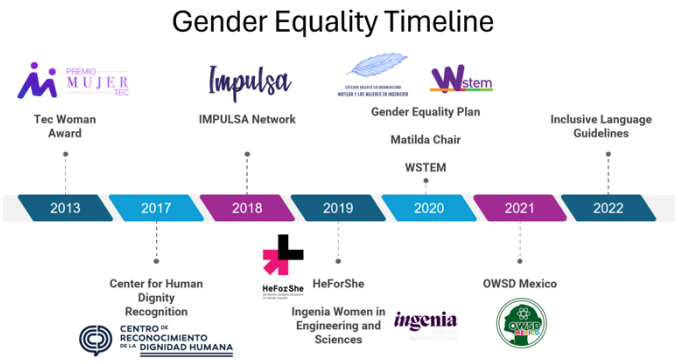

Fig. 1 Gender Equality Initiatives Timeline.

From the students' side, there are a variety of students groups that promote women empowerment, attraction, retention, and development to STEM careers. These groups organize forums and webinars with role models, provide training, collaborate with alumni and companies, participate in contests, and support other young women in STEM fields. Examples of these groups are WiSE Women in Science and Engineering, WIT Women in Technology, IEEE WIE Women in Engineering, Sacbé STEM, Women for the Future, Ada Women, and Space Makers.

The objective to encourage women´s participation in STEM careers extends to the wider community, with a particular emphasis on high school students who represent potential candidates for engineering programs. Therefore, our institutional communication campaigns are designed to disseminate messages that resonate with an intentional effort to achieve gender balance. This approach is evident in engineering program brochures, where equal representation of women and men is ensured. By featuring diverse visuals, young women can identify with the portrayed experiences, fostering engagement with the campaigns and serving as a source of motivation to consider and pursue these programs.

IV. Incoming and Graduating Student Data

From 2019, incoming engineering students have the possibility of selecting one of four "avenues" instead of declaring a program. These avenues are: Bioengineering and Chemical Processes (EBC), Applied Sciences (EAS), Computer Science and Information Technologies (EIT), and Innovation and Transformation (EIT). Later, typically at the beginning of their second year, students choose a specific program within their avenue. Table I shows which engineering programs belong to each avenue.

TABLE I
AVENUES AND RELATED PROGRAMS

Avenue	Programs
Bioengineering and Chemical Processes (EBC)	BAG, BFE, BBE, BSD, BCI
Applied Sciences (EAS)	BDM, BPE, BNE
Computer Science and Information Technologies (ECI)	BRD, BCT, BDT
Innovation and Transformation (EIT)	BC, BEC, BID, BIE, BM, BBM, BME

Over the past four years, not only has the number of female students that graduate grown consistently, as Fig. 2 shows, but this trend has also grown slightly faster than that of the total number of students who graduate, going from less than 31% females (2020 and 2021) to over 33% (2022 and 2023). On the other hand, the percentage of female incoming students has not deviated much from 31% in the last four incoming classes.

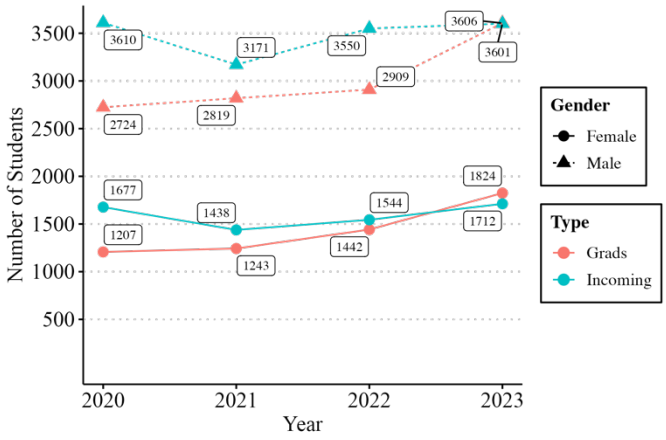

Fig. 2 Incoming and Graduating Engineering Classes

There are clear differences in female presence across the four avenues as shown in Fig.3, with EBC being the avenue with the largest percentage of female incoming students; between 56% and 57%, and the only avenue to have more incoming female than male students. Regarding total number of female students, while EBC and EIT had about the same number of incoming female students (about 670), they have clearly diverged since, with EIT having 833 incoming female students in 2023 and EBC having 512 in the same year. EAS has consistently had about 30% incoming female students, and EIT has also been relative stable at about 21% incoming female students. The total number of incoming female students in EAS has not varied much, while that of EIT has increased from 175 (2020) to 250 (2023).

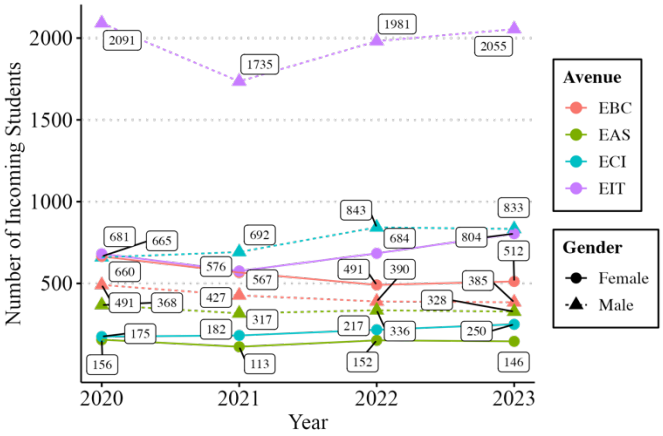

Fig. 3 Incoming Classes by Avenue

While there are big differences in terms of total student population across the university campuses, there are no significant differences in terms of female engineering student presence, as Fig.4 shows. Specifically, there is very little difference in the percentage of female graduating students when comparing the largest campus, Monterrey, with the university's national average. There is a small difference in the behavior of incoming students, with Monterrey having a slightly lower percentage of female students, although this gap disappears in the last year.

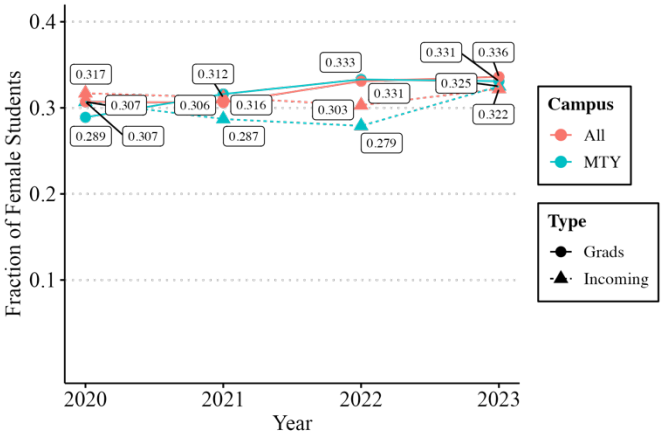

Fig. 4 Female representation in Largest Campus Vs all Campuses

Just as there are clear differences in female student presence across avenues for incoming classes, there are also considerable differences across programs when looking at graduating classes. The program with the largest proportion of graduating female students throughout the last four years is, by a large margin, Food Engineering (BFE) with 85%. Although, in terms of total female students graduated, Industrial and Systems Engineering (BIE) leads with 1437, followed by Biotechnology Engineering (BBE) with 1072. Table II shows the total number of students that graduated from each engineering program in the last 4 years, as well as the percentage of those students that are female. The number of "All" graduates shown does not coincide with the sum of graduates of each of the eighteen programs because there are a few students that have graduated in the past 4 years from programs that are no longer offered.

TABLE III
CUMULATIVE GRADUATING STUDENT DATA

Program	Graduates	Females	Program	Graduates	Females
BFE	310	85%	All	17774	32%
BBE	1702	63%	BEC	98	31%
BSD	619	58%	BDM	57	30%
BBM	562	52%	BEP	285	20%
BNE	119	43%	BRD	451	18%
BCI	916	41%	BC	1142	18%
BID	453	40%	BME	2778	17%
BIE	3885	37%	BCT	1716	16%
BDT	354	35%	BM	1750	12%
BAG	143	33%			

Most programs have not experienced significant changes in the percentage of graduates that are female throughout the last four years. Fig. 5 shows a few cases of interest: the programs with the largest total populations (BIE, BME) both have been very stable regarding female presence. The data for BBE, BCI, BCT, and BDT is also shown, and for these programs we can observe a trend of a moderate but sustained increase in female representation.

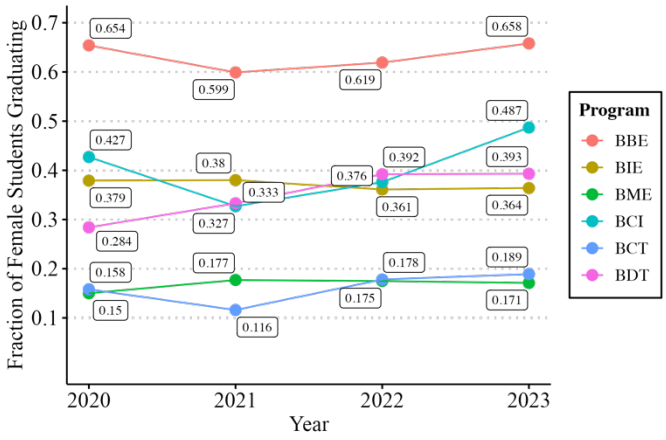

Fig. 5 Graduating Class Female Percentages for Selected Programs

V. RESULTS AND DISCUSSION

There does not seem to be a sizeable increase in female representation overall, both in freshmen and graduating student engineering classes in the past four years at a university-wide scale, although more work is needed to identify specific campus-program combinations where a noticeable trend may be developing. One interesting scenario is that of Biotechnology Engineering and Chemical Engineering; as well as Computer Science and Technology Engineering, all of which saw a marked decline in female representation in graduating classes

from 2020 to 2021 (10% for BCI and 5% for BBE and BCT) but have since then displayed consistent increases and have ended up with a greater female presence than in 2020. It is striking that when contrasting programs that are disciplinarily closest; Food Engineering for BBT, and Sustainable Development Engineering for BCI, don´t show the same behavior.

Perhaps not too striking is that the two programs that have, by far, the largest populations; Industrial and Systems Engineering, and Mechatronics Engineering, seem to be two of the most stable in terms of female representation, even though one has an above-average female presence (BIE) and one a below-average.

Certainly, a pattern emerges for the student body at our university, women seem to be more inclined towards biology-chemistry related programs (all six highest percentage programs), with more mechanical-leaning programs such as Mechanical Engineering, Mechatronics, Robotics and Engineering among the least popular options, percentagewise. This is not entirely surprising given that it has been reported that there is a sizeable gender gap in self-efficacy even while performing better in introductory physics courses [19, 20], a subject typically associated with mechanical-leaning programs; while for chemistry there are studies that show women having better performance as well as higher self-efficacy [20]. Smart et al. [21] observe that academic program choice is usually accompanied by a perception of strong abilities and interests in that discipline or area, which is closely related to self-efficacy.

Women faculty has engaged in the different institutional initiatives, promoting gender equity among their students and their colleagues. These professors usually give motivational talks, share their journeys as engineers, participate as mentors in mentoring programs, and work with different student groups looking into attracting, retaining, and developing women in engineering and sciences. These women are definitely role models for the students at our institution, and even though their presence has reaffirmed the career choice of many young women, there is still a way to go to achieve the much-needed cultural change.

VI. Conclusions

Our institution has undergone a transformative journey towards gender equity over the past decade. A variety of relevant initiatives have been implemented, each of them breaking barriers and having an important influence in the academic community. When analyzing the influence of these initiatives on the women representation in STEM programs, the results are not as promising as expected. However, the numbers are at least maintained and, in several cases, have shown an important increasing trend. In this context, there has been a significant advancement in fostering an institutional culture of equity and inclusion. Each specific initiative plays a role in this transformation, encouraging personal reflection and inspiring a sense of responsibility to serve as advocates for women´s empowerment. It is crucial that these efforts continue, enhancing the inclusive culture within the university and expanding their influence on the wider community. This collective commitment is essential for achieving gender equality in STEM fields.

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