How Academic Training in STEM Helps to Break Gender Barriers after Graduation

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***Abstract*—Recruiting more women into Science, Technology, Engineering and Medicine (STEM) programs has been a subject of study in recent decades. Many factors are involved in having lower numbers of admission of women into STEM programs, among them are the culture of the regions, the design of the programs, and the gender barriers. In recent years, it has been observed that women are increasing their participation in the professional context as more women graduate from STEM programs year after year. However, in some regions, the number of women continues to be very low. In this paper, we show how the educational process within the university can be a factor that can help break the gender barriers in the professional context, allowing women to access strategic positions in industry, and public and private sectors organizations and institutions. As it has been observed in different studies, there are two factors that commonly present and that are part of this work: the lack of job opportunities for women and the lack of professional role models for younger women that could inspire them to study a STEM program. In this study, we present the results of a survey that 80 young female engineers answered regarding their perception of what they have faced after graduation in terms of gender barriers, job searching and promotions and how the years in university and the competencies developed have made a difference.**

***Keywords*—STEM education, women in engineering, gender barriers**

I. Introduction

Since the decade of the 80s, several studies have been published on the number of women in STEM programs. These studies have shown that the reasons of low numbers of women are quite diverse from one region to another. However, most studies show that there is not a single factor that affects the number of women in such programs. The factors that affect the number of women enrolled in STEM programs are complex and there is always more than one main factor [1].

In a paper about the participation of women in STEM programs in Southern Mexico, it was found that cultural gender barriers are very important and also, the lack of role models in industry and/or government affects the decision of younger women when deciding what university program they would choose [2, 3]. However, this is not exclusive to this region, and as Blickenstaff mentions [4], there are 9 possible reasons for a low number of women in STEM in which also the gender barriers and the lack of role models were observed [5, 6].

On the other hand, Dasgupta [7] mentions that those 2 factors are present at different times, the lack of role models is present in their adult life whereas the gender bias is faced along their professional life. These two reasons are closely related as shown in Fig. 1.

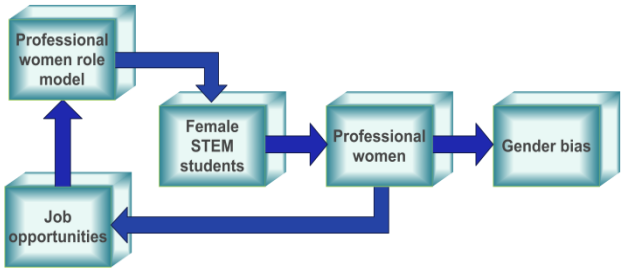

Fig. 1. Relationship between professional role models and gender bias.

Finquelievich [8] mentions the concept of e-Citizenship Science or Cyberscience, a term commonly used for the participation of citizens in scientific projects. A United Nations study on the use of Information Technologies for scientific projects discovered the lack of research papers oriented to gender studies.

Corbett [9] proposes a series of ideas for employers and educators in order to reduce the gender gap. One of his proposals is to include students in real life applications or projects, something that has been done for decades in universities but in some countries like Mexico, the access of female students to these activities is still an area of opportunity.

In more recent studies from 2020 [10, 11], some improvements are shown on the participation of women in the professional context, with 30% of women's participation in Europe, Asia, and Africa. For Latin America the participation of women in professional activities is around 50%, allowing having more and more role models for younger girls who might opt for a STEM program. The number of enrollment in STEM programs in Latin America is still a challenge that needs to be worked on. We think that there should be more projects such as W-STEM [11] in which women may identify themselves.

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Can universities provide more solutions, activities, or projects that could help female students reduce the gender gap in a more rapid manner?

II. Methodology

One of the main activities, a program director has in our university (name hidden for reviewing), is to support students in the academic processes and extracurricular activities. It is important to mention that we are currently undergoing a change in our educational model and that this research paper includes the perception of former students of the previous educational model since we still do not have graduations for the programs in the new model.

Any student can choose different opportunities in the last three semesters of her/his program. The options are detailed in Table I:

TABLE I. Options to Specialize in the Last 3 Semesters

Modalities	Definition
Internship	Internship or professional stay in a company. In this internship, the student works in a project that will have supervision from people at the company as well as guidance and supervision from a professor. The student needs to deliver positive results ensuring that the competences sought in this internship are achieved.
Semester-i	This modality is designed for the students to achieve a minor in a discipline offered in the title of the "semester-i". There is an industry partner and usually the group of students need to solve a project in coordination with the company/institution in which the project is developed. This minor has a curricular design approved by the academic authorities of our university. There is a group of professors teaching modules related to the minor.
Entrepreneurship	Students get courses on start ups and how to open a business, during a year, guided by professors from the Entrepreneurship Academic Department
Green Belt Certification	Training with external partners to get the Lean Six Sigma Green Belt Certification. Students take courses and examinations in a period of one year.
International Exchange	Students go abroad to a university that has signed a cooperation agreement with our university and the subjects that the student takes in that university are validated when she/he returns. The length of the international experience can vary from a summer course to a full year.
Double Degree	This is a modality with a signed agreement with a foreign university. Students from both universities go abroad in exchange and after a number of semesters, students get a degree from both universities. Students take courses in a different language and for that reason, they need to prepare in advance their foreign language level. Currently, we have a signed agreement with a consortium of over 20 German universities.
Concentration or specialty	This is basically a minor in one discipline, taught during one full semester with a set of courses on a particular discipline.
VW or Audi Internships in Germany (EMA)	This program is for Mexican Students in Germany, run in collaboration with the automotive companies VW and Audi. They take one semester of courses and one semester in a factory.

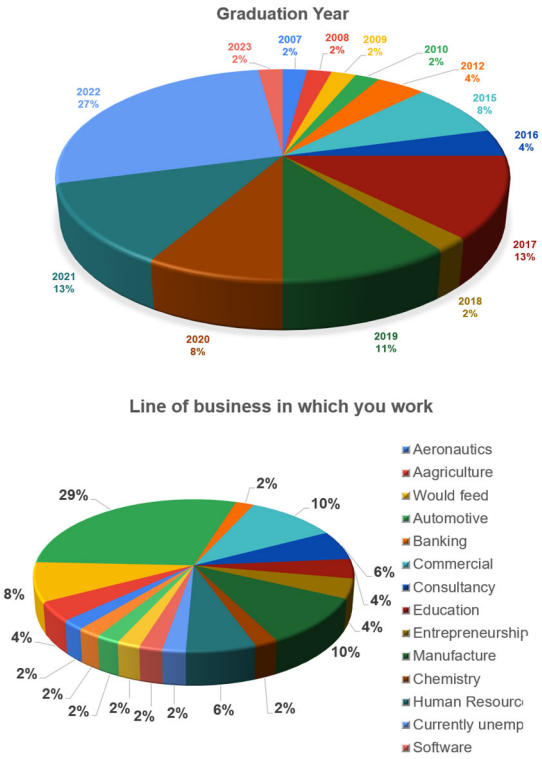

Fig. 2. Distribution of female engineers among the engineering programs.

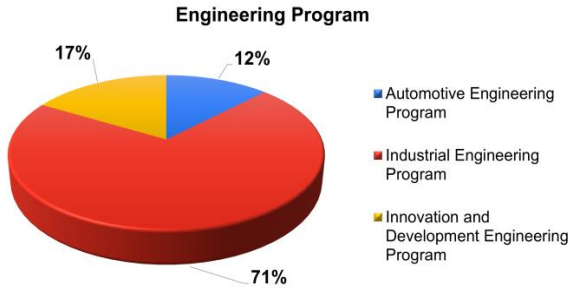

Fig. 3. Year of graduation (upper figure) and sector in which the female engineers are currently working.

In Fig. 2, we can see the years of graduation for the engineers and the sectors in which they currently work.

Each student chooses the modality that is best suited to her/his professional interests, according to the plan outlined with the aid of his program director. It is important to mention that the students are free to choose and there is no bias from the institution on what modality they should choose and they may opt out of the modalities scheme.

A survey was answered by a number of female engineers who studied their engineering degrees at our university. The survey covered several aspects of what challenges they faced after graduation as female

engineers. The objective was to reach a good number of engineers from the three different programs. A total of 80 engineers answered the survey, with a distribution shown in Fig. 3.

The answers that were received in the survey included engineers who graduated in the first generation of our university back in 2007 up to the last graduation in the first month of 2023. The information gathered from the answers shows that our graduates are working in different sectors, as many as fourteen different ones.

The survey was designed to know the perception of female graduates when they faced the labour market, considering first the workplace experiences they had during their studies and how these related to their professional experience.

III. Results

The results show the perception of 80 young female engineers who answered the survey. The first result is the number of professional experiences prior to their graduation, that is, during their nine semesters programs. Fig. 4 shows the number of experiences reported by the female engineers, in the graph we can see that all of them had at least 1 professional experience. The distribution is shown with some of them reporting up to five professional experiences. It is important to mention that entrepreneurship and certifications can be voluntary and without getting academic credits from the program.

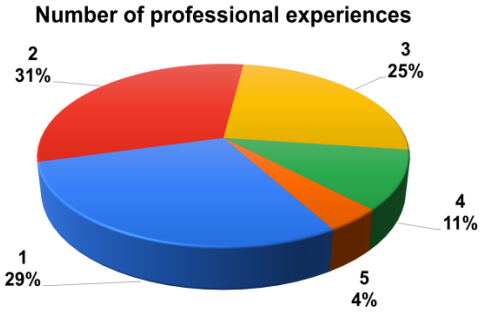

Fig. 4. Number of professional experiences reported by the young female engineers prior to their graduation.

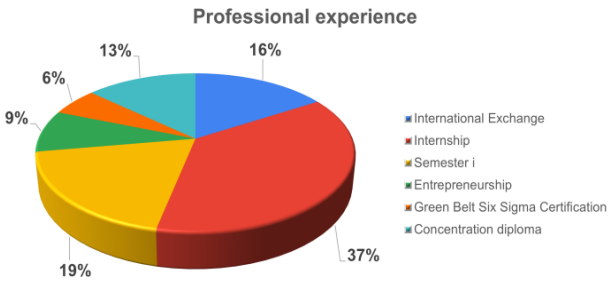

Fig. 5. Distribution of professional experiences among graduates.

Fig. 5 shows the distribution of professional experiences the female engineers had when they were students. 37% of them had an internship in a company related to their major, 19% of them participated in a "semester-i", 16% went abroad to study, 13% took a minor diploma or concentration, 9% took the courses from the Entrepreneurship department and 6% got the Green Belt in Six Sigma Certification. In Table I, you can see the definition of each professional experience.

As shown in Fig. 5, the "semester-i" and internships add to 56% of graduates. As mentioned in Table I, the participants of semester-i have to work closely with a company in a real project provided by the company or strategic partner and in most cases, students spend time at the company facilities during the semester. As Corbett suggested, it is important to involve female students in field activities [8].

In order to evaluate in an indirect way the impact the professional experiences during their studies had in their job seek, we asked these engineers the number of jobs they have had since their graduation. Fig. 6 shows that 79% of the graduates have not had more than two jobs. In this graph, the jobs are any kind of jobs, not necessarily jobs related to their degrees.

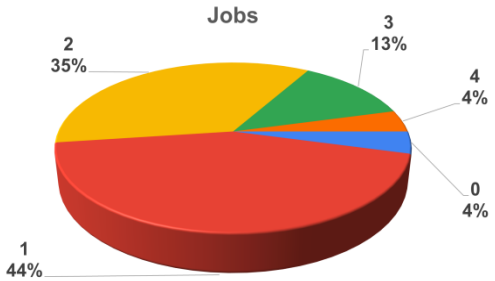

Fig. 6. Number of jobs the female engineers have had since their graduation.

The next question asked the female engineers to mention the number of professional positions or professional jobs related to their field of study. Fig. 7 shows these results. Note: In Figs. 6 and 7, the percentages reported as zero positions are for those who graduated at the beginning of 2023.

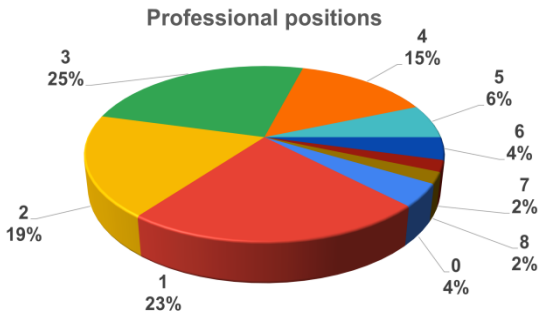

Fig. 7. Professional positions related to their field of study.

The next question was about promotions in their job. It is important to mention that the promotion does not imply a new job, as reported in Figs. 5 and 6. Fig. 8 shows the number of promotions the female engineers have had since starting their jobs and a surprising 56% of female engineers report that they had their first promotion in less than a year after starting their position. 25% mentioned that they had their first promotion after one year. The rest report promotions in periods no greater than five years.

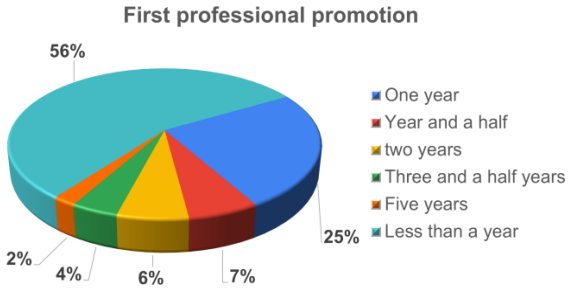

Fig. 8. Period of time for the first promotion.

Another analysis that was made with the engineers was to find out what sort of professional experiences they had during their studies for those who got their promotion in less than a year. Of this group, 29% had only one experience during their studies, and 42% had two different professional experiences. Fig. 9 shows these results and also, on the right hand side graph, the type of first professional experience for those with a promotion in less than a year.

Fig. 9. Professional experiences for female graduates that got a promotion in their first job in less than a year.

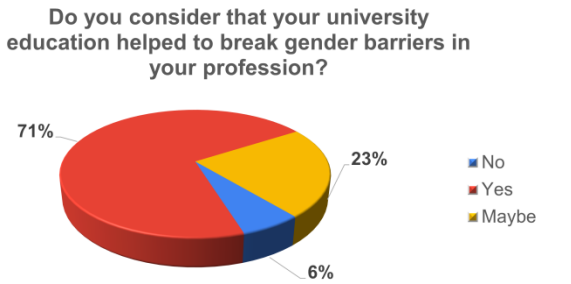

Fig. 10. How the professional experiences during studies helped in breaking gender barriers at work.

We also asked the female engineers about their perception on how the professional experiences before graduation contributed in a positive way to break gender barriers in their jobs, with 71% answering that the professional experiences were of great help, 23% considered that "maybe it helped" and only 6% replied with a "no help". Results are shown in Fig. 10.

The opinion and perception of our former students allow us to validate the importance of field activities or professional experiences in the formation of new female engineers as these might provide them with tools to face the still present gender barriers at the workplace.

IV. Future Research

In future research, we will focus on the new curricula or a new model for all engineering programs, namely Tec21, in which we have included professional experiences in most of the courses, as students have to solve challenges provided by strategic partners from the industry from the second year of their studies.

This future research will help us understand better the importance of professional activities during the studies of female engineers and how these activities provide them with better tools and experience to face the challenges of the still present gender gap at the workplace.

V. Conclusion

In this paper, we have shown the importance of professional activities or experiences during the studies of female engineering students. We can mention as important concluding remarks:

(1) It is important that all female students get at least one type of professional experience, such as internships during the duration of their engineering degree

(2) It is important to focus on female students and design activities exclusively for women in which they also learn of professional role models (successful women in Engineering)

(3) We recommend to have as first professional experience a field activity as those provided through internships or our "semester-i" and as a second choice, international experience with a semester of study abroad.

(4) Have a good database of strategic partners in the industry that seek the same objectives of reducing the gender gap

We present this work as a foundation process that could be used in other developing countries universities or any other country where the gender gap is still an area of opportunity and we have seen that the perception of our former students encourages us to continue in the same path of providing female students with tools to face the challenges of the workplace.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Israel Zamora-Hernandez conducted the research and wrote some sections of the paper; Jorge Gonzalez-

Mendivil analyzed the data; Miguel X. Rodriguez-Paz wrote the paper and proofread it; all authors had approved the final version.

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