Chapter #25

WOMEN IN ENGINEERING: ACTIONS FOR IMPROVING THEIR INTEGRATION IN THE FACULTY OF ENGINEERING IN BILBAO

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ABSTRACT
The situation of women in the engineering world has different aspects that should be carefully analysed. Last century, the woman who first broke this taboo in Spain was the mayor of Bilbao, the first female industrial engineer graduated in Spain in 1929, Pilar Careaga. By means of her public presence, her message could reach general society, but only as something exceptional. At the Faculty of Engineering in Bilbao, the first female Industrial Engineer was Pilar Ipiña, who graduated in 1965. Thirty six years later.
After nearly a century, women in engineering remain a clear minority. Proposing solutions requires knowing the causes, in order to be able to carry out actions that lead to harnessing women's talent and enable them to realise their full potential.
This paper presents a multi-staged process for the integration of women in engineering degrees. The first stage analyses different issues about the faculty structure and regulations. The second stage relates educational objectives and the gender perspective. The third stage marks the importance of educational materials. The fourth stage summarizes educational methodologies and activities. The fifth stage proposes a change of assessment model. Finally, the sixth stage comments on the importance of control and visualization of results.

Keywords: women in engineering, engineering education, gender equality.

1. INTRODUCTION

During childhood and adolescence, school, high school and university are a very important source of references for children. These referents are a fundamental factor in the perception of what is appropriate or accessible for girls. However, these examples of women that girls may want to emulate should be close at hand, not only famous or important. A woman astronaut or Nobel laureate may be admirable, but she can seem to be something unattainable and therefore impossible to imitate. However, many teachers of physics and chemistry, technical drawing or mathematics are women; and they can be a more influencing factor, being examples of an achievable goal, from the viewpoint that technology, engineering and science are girls' things (Ayuso et al., 2019).

The family environment also plays a fundamental role when choosing the field in which to pursue higher education. Not discouraging girls with comments about the difficulty of science or engineering studies is very important. Not dissuading them from a fascinating world where discoveries, pure research, and inventions are waiting for their talent is also essential (Ayuso et al., 2020).

Actions are being developed from the university world and from professional associations to promote that female talent is not lost in these areas. Actions are being taken to explain all these possibilities to girls and young women. However, it is no less important that the family and community are informed and aware. Girls have no problem with science and technology subjects, and it should be natural for them to enjoy those disciplines. Interesting texts, histories and information about women in science and technology can bring not just girls, but families, closer to the world of science and engineering (Tietjen & Reynolds, 1999).

Social mobility could be defined as the movement from one social position to another. University studies in engineering are linked to social mobility, including possibilities of employment, something important for equal opportunities for boys and girls. Continuing studies differentiate even more for women than for men (Neglia, Tragodara, Paragulla, & Caceres, 2020).

In terms of probability of attaining higher education, Spain is in position 8 out of 20 European countries. This has improved when compared with previous generations (CRUE, 2018). Among people from 45 to 59 years of age, the percentage of adults who attained higher education and whose parents did not is 16%, and among those from 30 to 44 it improves to 21% (CRUE, 2018).

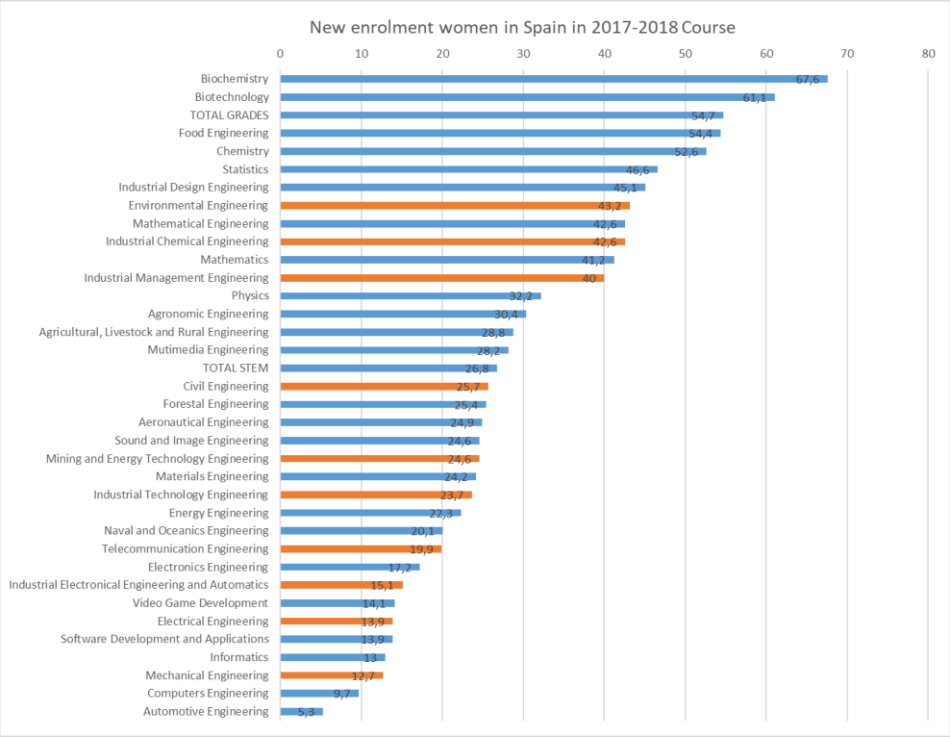
An important piece of information to assess the possibility of social mobility is the number of universities in Spain and their territorial distribution. There are 50 public universities and 34 private universities in Spain (CRUE, 2019). The geographical proximity favours the families that can financially support young people's access to university studies. From the data (CRUE, 2018), (CRUE, 2019) it can be seen that the percentage of women who access higher education is greater than that of men.

Figure 1 shows a report on Public Universities in Spain (CRUE, 2019) about women's first enrolment. The orange colour corresponds to ten of the twelve Bachelor's Degrees of the Faculty of Engineering in Bilbao, it can be observed that three of them are above the average TOTAL STEM and seven below the average.

Reversing this trend and attracting women who like and are interested in engineering fields is a social objective that will be a benefit to all (De Carvalho Fernandes et al., 2019).

The main contributions of this paper are to demonstrate the existing situation of persistent inequality of women in academia and industry, and the proposal of different actions to effect change for improving the integration of women in engineering degrees.

Figure 1.
Women´s first enrolment in Public Universities in Spain.



2. WOMEN IN ACADEMIA. THE FACULTY OF ENGINEERING IN BILBAO

Once women enrol in engineering studies at the university, even today, they are entering into a very masculine environment. The classroom environment is generally friendlier and without gender considerations. In the 1960s, 70s, and 80s, the female presence was token but the student experience was generally satisfactory (Udén, 2002). Normality in dealing with teachers and male students was the standard then and continues to be so today. No differentiating attitudes were perceived by gender, neither by the teaching staff nor by the peers.

In the Faculty of Engineering in Bilbao in the 90s, five women and ninety-five men were in their sixth year of Industrial Engineering, Mechanical Degree. Considering 2014/15 to 2019/20 courses, 30 years later, the average ratio of enrolled women is 13%.

The Faculty of Engineering in Bilbao has 4702 enrolled students, distributed into twelve engineering bachelor's degrees and eighteen master's degrees in 2019/20 study year.

Figure 2 shows two blocks of graphics, the first block of four showing the gender distribution for the new incoming students of four bachelor's degrees and, the second block of one showing the percentage of total new incoming women in the Faculty of Engineering in Bilbao. These graphics clearly display and confirm the reality that women in engineering

degrees are a small proportion of the total students and the tendency has not improved during this period.

On the other hand, it is important to highlight that, for example, the dropout rate in the first year of undergraduate studies is lower among women, 18.1% compared to 23.2% for men (CRUE 2018) and that the percentage of credits passed compared to those enrolled, continues to be higher among women, 73.2% compared to 66.5% for men (CRUE 2018). These examples, among others indicated by the 2018 Conference of University Rectors of Spain, corroborate the good academic performance of women in engineering degrees.

Figure 2.
New incoming students in four bachelor's degrees and total new incoming women in the Faculty of Engineering in Bilbao, 2014/15 to 2019/2020 courses.

It seems clear, in view of the aforementioned data, that female engineering students are perfectly equipped for these studies. These data should demonstrate and reinforce that there is no objective reason that should discourage nor deter ambitious young women from deciding on their course of studies and professional future (Mozahem, Ghanem, Hamied, & Shoujaa, 2019).

3. THE WORK ENVIRONMENT AND THE GLASS CEILING

The career of the professional engineer is a very flexible profession, as the fields of knowledge in these careers are highly diverse. In addition, the engineering graduate will be able to begin practicing their profession after obtaining their title without any additional requirement. These two circumstances allow the entrance into the work environment with certain ease. Industry, academia, research, administration and business are different areas where engineers can develop their professional life.

University studies provide a qualification that generally allows graduates to achieve quality employment. One of the objectives of the students is to have successful access to employment, and the data demonstrates that a university education fulfils this purpose (Ministry of Science, Innovation and Universities, 2018). However, today there are still both a wage gap and a higher unemployment rate for women (Cadaret, Hartung, Subich & Weigold, 2017). Many women still face the double challenge: that of moving up socially and that of breaking different barriers of inequality, such as the 'pregnancy penalty' (Vella, 2020).

Taking public universities and administration in Spain as an example of women in different work positions, Table 1 shows the differences between men and women (Ministry of Science, Innovation and Universities, 2018). The results are revealing and show a gender inequality that could be extrapolated to other environments, especially taking into account that gender polices are regulated through different laws in the Spanish public administration. In industry, the data reveals similar differences (Fouad, Singh, Cappaert, Chang, & Wan, 2016). In their research, the aforementioned authors analyse the twenty percent of engineering graduates in the United States who are women and why only eleven percent of them become engineers. In this way, what are the factors that differentiate women entering, staying or leaving the engineering profession?

Table 1.
Ratio women/men in University and Government institutions in Spain, 2018.

	Universities in Spain	**Universities in Spain**	**Faculties in Spain**	**Faculties in Spain**	**Research Institutes in Spain**	**Public Institutions in Spain**	**Public Institutions in Spain**	**Faculty Engineering in Bilbao**
	Rectors/ deans	*Vice-rectors*	*Faculty directors*	*Vice-directors*	*Directors*	*Grade D, the lowest*	*Grade A, the highest*	*Lecturers*
Women	2%	39%	27%	47%	19%	58%	25%	34%
Men	98%	61%	73%	53%	81%	42%	75%	66%

When analysing the impact that studying science and engineering has on female university graduates, one could say that there is good news. The higher the qualification, the better the employment rate. In addition, the fields of engineering and science have one of the highest occupancy rates. Combining both factors, these are even more compelling reasons to encourage women to choose these studies (Mills, Gill, Sharp, & Franzway, 2011).

The engineering work environment is one of the most complex ones for women. The main example of this complexity is the continuing difficulty for women to access management positions (Jung & Kim, 2020). Many highly trained and experienced women, including those without children, have hit the ubiquitous 'glass ceiling'. This is a term that, for too many years, has come to define the differing and limiting career prospects for women when compared with men (Tang, 1997).

4. POSSIBLE ACTIONS FOR THE INTEGRATION OF WOMEN IN ENGINEERING DEGREES

Engineering is one of the career fields where women's underrepresentation has been persistent (Jung & Kim, 2020). Frequently the associated research studies about this situation have shown a poor evaluation: convenience samples, limited circles of acquaintances, and personal experiences (Frehill, Di Fabio, Layne, Johnson, & Hood, 2006).

The Faculty of Engineering in Bilbao and the University of the Basque Country promote different actions for improving the integration of women in engineering degrees. These actions are implemented in six stages. The first stage analyses different issues about the faculty structure and regulations for a better integration of women in the engineering degrees. The second stage relates educational objectives and the gender perspective, underlining the impact of the low number of women in students' groups. The third stage highlights the importance of educational materials as sources of reference for women. The fourth stage summarizes educational methodologies and activities for empowering women when team working with other students. The fifth stage proposes changes in the assessment model. Finally, the sixth stage underlines the importance of the control of results for improving the visualization of women´s achievements as new sources of reference.

4.1. Degree variables related with faculty structure

Many factors have an influence in the gender equality and integration of women in the engineering degrees (Makarem & Wang, 2019). The following data are based on the Basque Country University, in the Faculty of Engineering in Bilbao and some of the data with respect to a specific Bachelor's Degree (BD).

A first factor is the example given by the educational staff. In the Industry Electronics and Automation BD there are 84 men and 51 women. The resultant percentage of 37.7% women, gives a skewed vision of technology as being masculine (Transparency Portal in the University of the Basque Country, 2021). A second factor is the percentage of female students. In the same BD for example, only 18% of students are women. A third factor is related with management positions in the faculty. There has, as yet, never been a woman Director (Equality in numbers in the University of the Basque Country, 2021). All these documents demonstrate the general gender inequality for women in the Basque Country University.

During the last ten years, different regulations have been developed in order to correct the above situations. An example of these regulations in the Basque Country University is the search for strategies to attain the equality of women with men (Equality Plan for Women and Men in the University of the Basque Country: 2019-2022, 2019). These regulations are based on Spanish Laws that establish general rules, for both public administration and private companies (Law 3/2007 of March 22nd, 2019). The equality, which these laws and regulations promote, refers not only to the starting conditions, access to rights, to power, and to economic and social resources and benefits, but also to the conditions for their effective exercise and control.

However, despite all these regulations, it must be said that there are no specific considerations of the gender perspective in the study plans of the Engineering Faculty of the University of the Basque Country. Nor is information collected on the degree of satisfaction of the students with respect to how the gender perspective is addressed in the degree course. An explanation for this anomaly is the presumption that there is not a problem. Perhaps because women, "apparently", are perfectly integrated in the different degree courses.

The training actions are possibly the main factors that could be useful to highlight the real situation of women and help to improve it. Table 2 shows online courses 2020-21 data at the Basque Country University level, with 824 accredited people (Directorate for Equality of the University of the Basque Country, Report 2020).

Table 2.
Gender online courses 2020-21 data at the Basque Country University.

ONLINE COURSE	DURATION	PLACES	INSCRIPTIONS				ACCREDITED PERSONS			
			WOMEN	MEN	NON-BINARIES	TOTAL	WOMEN	MEN	NON-BINARIES	TOTAL
Equality of women and men	25 hours	200	381	41	3	**425**	130	14	2	**146**
Inclusive language	25 hours	200	333	58	4	**395**	104	19	1	**124**
Masculinities. Men and equality: challenges and resistance.	25 hours	200	205	60	7	**272**	98	25	1	**124**
Sexual diversity	30 hours	200	227	40	9	**276**	82	17	5	**104**
Co-education promotion	75 hours	100	92	30	4	**126**	49	13	1	**63**
Child sexual abuse	30 hours	200	293	43	6	**342**	120	9	3	**132**
Violence against women	25 hours	200	208	24	4	**236**	117	11	3	**131**
TOTAL		**1300**	**1739**	**296**	**37**	**2072**	**700**	**108**	**16**	**824**

4.2. Educational objectives

The educational objectives in engineering faculties are stated with verbs like: remember, analyze, apply, identify, formulate, solve, evaluate, among many others. However, rarely are they used with regard to gender perspective. It does not seem to matter that the enrolment numbers for women students have come to a standstill for the last ten years, Figure 2. However, the educational objectives should be based on integral actions towards the recognition of women in engineering, not only in university but also in their future professional commitments (Ayuso et al., 2019).

Active and cooperative methodologies are well developed through Problem and Project-Based Learning methodologies (PBL), one of the most widespread cooperative methodologies in engineering degrees. In these methodologies, the educational objectives are developed in a common mode based on student work groups. The students are distributed with different gender members. There may be groups that do not have any women, groups that have one, two or three. What is very rare is to find groups of females only students, and this situation is justified because there are few women. The reasons for attracting or preventing their presence in work groups are based on the support that women receive, and to understand how they feel will be important to developing their future careers (De Carvalho Fernandes et al., 2019).

If the educational objectives could be divided into theoretical and experimental, perhaps some answer to the dilemma posed could be found. There is a common idea related with women that they are more cautious when manipulating experimental artifacts which have a certain degree of risk. The perceived idea is that women students are more reflective than their male teammates.

An educational objective for the years ahead is to change this false perception. This will be attained by improving the leadership levels of women in complex experimental activities related to the handling of educational and research equipment (Isaacson et al., 2020), and by normalizing industrial objectives in the focus of women (Mozahem et al., 2019).

4.3. Educational materials

The role of gender in shaping achievement motivation has a long history. The gender differences between girls' and boys' related with beliefs and behaviors continue to follow gender role stereotypes (Meece, Glienke, & Burg, 2006). The importance of academic self-efficacy and positive identity can help generate a constructive interaction for supporting the career development of women in engineering fields (Cadaret et al., 2017). In this way, inclusion of women in STEM positions in the educational material can play an important role as referent models for young women.

With a teaching staff that is mostly male, the gender perspective in the selection and elaboration of educational materials goes unnoticed. In engineering faculties, the majority of educational materials and bibliographies are elaborated by men, hence, the point of view and framework for the resolution of problems is masculinized. This is a complex problem because it requires the commitment and compromise of men and women to change this situation and to incorporate a feminization in an elaboration of new and revised educational materials (Mills et al., 2011).

The improvement in the selection and elaboration of materials will be focused on the works and contributions made by women in the field and with a bibliography in which the first author is a woman. The educational use of selected projects carried out by female students, either from previous courses from final degree and master's projects, can help in this task. The incorporation and visualization of these works as educational examples can help and encourage female students to persevere with their studies in engineering (Fouad et al., 2016), as well as, to close the gender gap (Tietjen & Reynolds, 1999).

4.4. Educational methodology and activities

The active and cooperative methodologies, like Problem-Based Learning, Project-Based Learning, Challenge-Based Learning and Research-Based Learning, among others, have been widely implemented in the engineering faculties for years (Mills & Treagust, 2003). These methodologies have been well balanced to resolve "actual questions" through "real world" scenarios, developing different competencies in education related with technological and social skills. In these methodologies, the gender perspective has not always been a priority. The lack of recognition of the existence of the problem has meant that no measures have been taken to correct it (Udén, 2002). Recent research suggests that the integration of engineering and humanities perspectives in these methodologies promote better learning benefits for female engineering students (Stolk & Martello, 2015). It is the interaction in student groups, where gender roles are more evident and, this is where an opportunity for improvement arises (Hirshfield & Su, 2017).

The improvement in classroom activities and dynamics, methodologies, and general organization skills for female students can and will be attained through their empowerment in their roles and with their responsibilities within the working groups (Neglia et al., 2020). This positive discrimination in the student teamwork leadership recognizes and redresses a hidden situation and revitalizes all classroom activities. Nevertheless, in actuality, this positive discrimination may have little effect with the general dynamic as women only make up twenty percent of classroom students. However, it is expected that it will have an influence in coming years (Fowler & Koretsky, 2018).

4.5. Assessment

The assessment is an educational activity that should be changing from the traditional written examination forms focused on technical knowledge and skills. These changes could include a range of other skills more identified with female students, such as, social implications, human necessities and environmental concerns (Du & Kolmos, 2009). The application of PBL methodologies will help to transfer the weight of assessment to another system more related with grouped activities where women are generally better integrated (Zastavker, Ong, & Page, 2006). The above recommendation seeks to promote other complex competencies assuming that the technological knowledge and skills are sufficiently developed in the engineering faculties.

The use of questionnaires in platforms like Moodle can help in this task, because it allows for the time management with different asynchronous and synchronous activities. These platforms do not have tools for gender analysis that allow for an understanding of gender difference. Tools for analysis based on the collection of data and the subsequent interpretations should be made for obtaining statistics focused on gender.

4.6. Results control

Results indicate that female engineers continue to face significant hurdles in both social and professional environments (Mozahem et al., 2019). The multidisciplinary research project results promoted by women for solving complex world problems should have been an attraction pole for women when considering studies in engineering (Mills et al., 2011).

Female role models for women in engineering in Spain were until recently few and far between. Pilar Careaga, from the province of Bizkaia, was the first woman to enrol and then graduate as an engineer in Spain in 1929. She eventually went on to become the first female Mayor of Bilbao. The first woman to graduate as an engineer in the Basque autonomous region was Pilar Ipiña in 1965. Marrying soon after graduating (to an engineer) her career as an engineer was not encouraged and put on hold to attend domestic duties. While these women were and still are important examples of breaking with tradition and their encountering of traditional boundaries, their stories, their engineering career paths are not well known nor well documented. This however does not need to be the case today where examples of female engineers and their accomplishments are readily available and well documented. This is especially so, when taking into account the omnipresence of the social network. The control and visualization of a selection of women engineers and their stories and accomplishments, from local and global contexts can encourage and reinforce and provide the examples young women need when they are deciding what to study.

5. CONCLUSIONS AND FUTURE WORK

Exploring solutions for the gender differences in the engineering and technology fields is a complex problem. Equitable representation of women is essential for the normalization of the female presence. It is necessary that female engineers are working to their abilities and developing their talents to make their presence normal, and in this way, they must reach decision-making positions.

In primary and secondary education, having female references in the engineering fields helps normalize girls' vision of their possible career choice in the engineering and technology fields. Visibility of women who work in engineering and science must be promoted so that it is perceived as something normal and that these are options that can be chosen with the same spontaneity with which girls choose to be a doctor, a psychologist, or a teacher.

The fear of an insufficient professional projection after very demanding studies can also keep girls away from the world of engineering. However, the reality of women engineer's employment opportunities, with a high professional category in industry is also motivating.

It must be recognized that in order to change a situation such as this one, with its great internal inertia, actions must be taken to break the current imbalance. In this paper, different actions have been outlined such as a six stage program for improving the integration of women in engineering degrees, a re-evaluation of the gender bias in engineering, a re-evaluation of educational materials, methodologies, workshop practices and assessment, and the importance of role models for aspiring female engineers.

These actions can help to empower women in their careers and in this way improve their integration in the industrial world.

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