Integral Actions Towards Women in Engineering Recognition

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***Abstract*—This work presents integral actions towards women in engineering recognition organized according to educational stages they are directed: Stage 1, from early childhood education, primary education and secondary education; Stage 2, during university and Stage 3 after university. At stage 1 actions are devised to increase girl's interest on Science, Technology, Engineering and Mathematics (STEM). Emphasis is put on showing women in engineering as role models, illustrating engineers work and stressing the importance of diversity in working groups. Stage 2 is focused on making male and female students aware of the gender gap in engineering and the importance of diversity for innovation and training female students on known female narrow circumstances. Finally, at stage 3, the objective is to retain and promote women in the engineering profession. The specific actions developed at the three stages are presented. Their impact is discussed in order to accomplish effective actions for achieving gender balance towards excellence in Engineering.**

***Index Terms*—women in engineering, gender balance, vocations, mentoring, leadership, recognition**

I. Introduction

Women in engineering have existed before the development of the profession of engineering. This began as a formal academic discipline at the late 18th and early 19th centuries. However, women were admitted to engineering programs since the 20th century [1]. According to the UNESCO Science Report: towards 2030 [2], women are consistently underrepresented in engineering and related fields. In Europe and North America, the number of female graduates in engineering, physics, mathematics and computer science, usually known as STEM, is generally low. Women make up just 19% of engineers in Canada, Germany and the USA. Computer science quotes the lowest presence of women worldwide where there is a steady decrease in female graduates since 2000 that is particularly marked in high-income countries. As a result, on 20 December 2013, United Nations adopted a resolution in which it recognized that full and equal access to and participation in science, technology and innovation for women and girls of all ages was imperative for achieving gender equality and the empowerment of women and girls.

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The problem is considered complex because of the multiple factors involved and this is often represented by the metaphor of a "leaky pipe line" of women from secondary school through university and on to professional career [3].

Therefore, the actions presented in this work covers all ages. This provides an invaluable feedback as the problem is observed as a whole. Section II presents actions planned covering early childhood education, primary education, secondary education and tertiary (or higher) education. In Section III, actions programmed during the engineering studies are introduced. Section IV compiles actions at the graduate level. Finally, main conclusions and future steps are given in Section V.

II. Actions to Schoolchild

Nowadays, there are relevant initiatives worldwide to attract more women to Science, Technology, Engineering and Mathematics (STEM). However, most of them only include the most excellent students or bring girls previously interested in technology as "Inspiring Girls", "Stem Talent Girls" or "Women Techmakers Scholars Program" [4]. One key aspect of the following activities is that they are directed to educational centers. This is determinant in order to include a broad portion of children and young people and to involve educators to change those factors that are under their control.

The next actions are sorted chronologically because they were developed subsequent to the activities in course.

A. Girl's day

The Girls' Day is an event organized at University of Zaragoza (Aragón, Spain) from 2008. It consists on one day in which women who play important roles, either in business or research, introduce students of secondary education into science, engineering and technology. The aim of the activity is to show examples of engineering products developed by teams that are led by women or that include women, in order to give reference models of women working in engineering and technological fields.

The event is aimed to students attending last years of High School, what corresponds in the Spanish Education System to the third and fourth year of Compulsory Secondary Education (ESO: *Educación Secundaria Obligatoria*) and bachelors.

During the different editions, some minor changes have been made. The main differences between the editions were mostly on how the students traveled to the venue (subsidized transport, public transport, on their own, etc.), if it was focused only for female or for mixed groups of female and male students participated, the duration of visits (full day or not), the implication of companies and the size of the groups.

The visits of the student to the event were organized similarly in the different editions: attendance to plenary sessions, arrangement of small groups for the interactive activities and satisfaction surveys and farewell final activities. For a full description of the event, see [5]–[7].

In the plenary sessions, a welcome speech is given by female professors of the Engineering Campus of the University of Zaragoza, in order to present a complementary vision of what engineering is and prepares the visitors for the activity. Whenever it is possible, recently graduated female students explained their experience: they talked in detail why they chose their degree and where they currently worked. This quite informal talk was very helpful for motivating students to the choice of a degree related to engineering and technology.

The activities intended that participants in small groups get contact with different branches of engineering and technology, by performing small tasks that were appealing. This is the central part of the event, and consists of women engineer showing their own work and engineering female students guiding the tours around the different laboratories, groups and companies. During the different editions of the Girls' Day, there different kind of activities, guided tours, workshops and other hands-on activities organized by the research groups of the University of Zaragoza. In addition, the Girls' Day journey has also had the participation of numerous industry-related engineering, technology and communication companies: well-known national and international companies have participated in some of the editions.

Before the farewell of the participating groups, they were requested to fill in an individual survey. The objective was double. On one hand, we wanted to have mechanisms to assess the scope of the event and to improve the organization of future editions, but also, with these surveys we wanted to obtain information about the reasons of students' choice of engineering studies.

The results reflected that the activity has a very positive impact on informing students about engineering, improving their knowledge and perception of engineering in general, and in showing the under representation of women in this kind of professions. However, regarding motivating women to pursue engineering careers, the survey confirmed us that actions must be done much earlier than in High School, since at that time most women had already decided not to do engineering or technological careers [6].

B. WikinformáticA!

WikinformáticA! en Aragón [8] is a competition organized by the University of Zaragoza from 2015. It involves student groups in which each team develop a set of articles about prominent women in the history of Information and Communication Technology (ICT) collaboratively in a wiki platform. In more detail, teams of students from high school and last courses of primary education make Wikis about technologists or scientists related to ICT. First of all, they must to find out the name of certain relevant women from different clues. After that, they must create articles about these women in a Wiki format.

The main goals of this competition are:

1) Increasing the visibility of prominent women involved in ICT, especially the ones that have worked or studied in the University of Zaragoza. Despite the fact that there exists a wide number of prominent women that have contributed to the development of ICT, a great percentage of them do not appear on websites such as Wikipedia. So, the participants must create articles about prominent women proposed by the organization of the competition in order to know their achievements and disseminate their works.
2) Promoting the use of Wikis and collaborative work among participants. Despite the fact that creating and editing Wikipedia articles is an easy and free task, less than 15% of Wikipedia (the largest encyclopedia most consulted, nowadays) editors are women. So, the groups of students must develop their articles in a Wiki platform in order to show them that editing Wikipedia articles is possible without a big effort.
3) Encourage participants, especially students, to analyze the quality of information and data sources in order to reduce and avoid the dissemination of wrong data or fake news. Thus, they need to search for information and reliable data sources and, after that, they must create articles and publish them in a Wiki platform collaboratively.

To achieve these goals, students must create teams composed of a minimum of three and a maximum of 8 people. Due to the fact that teams are composed of adolescents or children, and that the current legislation about personal data and privacy is quite restrictive, each team is leaded by a teacher (or supervisor). In this way, the organization of the contest only requires the data of the teacher in order to allow a team of students to register in and participate in the contest. In addition, the teacher acts as a supervisor of the student team.

Since the first edition, the number of participants have been increasing significantly. In the first edition there were 95 participants organized in 9 different teams (maximum 15 people per team). Thus, in the second edition, there were 207 participants organized in 33 teams, while in the third edition, there were 234 participants organized in 45 different teams. In the last edition of the contest *WikinformáticA! in Aragón* in 2018, more than 700 students from different schools organized in 135 teams signed up and completed their works on time. So, we consider that the results achieved so far have been satisfactory, especially in the last edition, where the participation has increased considerably.

C. A female engineering at every school

One of the key stages to perform actions to attract the interest of girls on STEM is at an early age, since the gender gap associated to STEM studies appears at the age of six [9].

In our program "A female engineering at every school" we show to young students the work that is carried out by engineers and scientists, with the aim of attracting their interest on STEM. In order to mitigate the gender gap in the field, we provide first-hand examples of women working in engineering, and we encourage diversity in working groups.

We have already carried out this activity for four years (2016 to 2019) [6], [10]–[12]. Every spring, we make a call and look for volunteers, which are usually women with professional careers related to STEM (from private companies, academics, and research institutions), as well as undergraduate students enrolled in courses related to STEM (usually, from the University of Zaragoza). Our volunteers visit primary schools and make an activity with the students. Usually, they start explaining their work or their studies as engineers, mathematicians, chemists, etc., connecting these ideas with daily life examples. Then, they make a workshop activity with the students organized in small groups. These workshops are selected so that they are related to STEM activities, and so that children play games as they learn the concepts. The key idea is to show students what engineers and scientists do, that engineering and science is fun, exciting, and useful to society, and that they can become engineers and scientists as they grow up. Some examples of workshops include "Resistant structures with beautiful and tasty materials", "A polythylene thermocutter", "How do we treat water?", "Augmented reality", "How does a computer store images?", "Building a robotic hand", "Encrypting messages", or "Building an electrical car", among others. Every edition, the activity gains more interest. In 2016, 40 engineers visited 20 primary schools, explaining how cool STEM is to 1000 children. The last edition (2018), more than 100 volunteers visited 70 schools and presented the activity to more than 3000 students. We are performing the current edition (2019), with more than 170 volunteers enrolled. Up to now, 76 volunteers have already completed the activity, having visited more than 40 schools and more than 2000 students. Our volunteers have a wide range of profiles, including several engineering branches (e.g., tele–communication (20%), computer (17%), chemical (10%) and mechanical engineering (7%)), as well as science profiles (we have volunteers from mathmatics, optics and optometry, or chemistry among others). We asked the volunteers about their motivation to participate in the activity, and the most popular reasons include: "To promote equality of opportunities in STEM" (75%), "To improve the visibility of the contributions of women to science and technology" (70%), and "To make engineering, science, and technology more accessible to the general public" (67%).

In 2017, "A female engineering at every school" was granted with the award "Third Milenium: Science Dissemination". These awards are organized by the Spanish newspaper "HERALDO" to acknowledge the actions carried out by individuals, companies, or research groups, with the aim of disseminating science and technology, making it more accessible to society.

III. Actions at the level of Higher Education

While guidance, visibility and awareness are key during the early stages of education to improve the presence of women in STEM in the future, we have also directed our attention towards women currently seeking to pursue a professional career. In particular, we have tried to reach women studying Engineering degrees in the University of Zaragoza, at both undergraduate and graduate levels, through a mentoring program. Women are a minority in many of the undergraduate Engineering degrees at University of Zaragoza (in mean 25 % being < 10 % in Computer Science); the goal of this mentoring program is to provide them with tools that will help them succeed in their respective careers, both during university and after their studies [13].

The methodology followed in this program consists in a number of plenary sessions aimed at all the female students in the School of Engineering at University of Zaragoza; male students are also welcome to attend the sessions, although the focus is on female students. The sessions conducted cover a wide variety of topics, including: gaining awareness of the existing gender inequalities during the professional career, and possible solutions; improving self-confidence; working on assertive communication; or round tables with women who are currently successful professionals working in engineering-related areas. Attendees conduct a poll after the sessions, and analysis of the results allows to establish or improve certain areas for future editions.

The mentoring program is a project of the "Incentive Program of the Orientation Plan at the University of Zaragoza". This fully supports all the actions devised and implemented by the teachers involved in the project. The first edition took place during the academic course 2018-2019 [14]. In the current edition the number of teachers participants and the budget have been increased. Despite a poll answered by 248 female students showed the interests in the project and sessions have been promoted among the students, participation is being very low with a mean attendance of 30 students. Among the reasons behind this fact may be the overlap with other academic and complementary activities and the lack of an academic reward.

Consequently, we are considering the continuity of the project. It is mandatory to devise it from the objectives to the actions to attain students. Maybe the efforts should be put into the conscious of teachers about the gender gap and fostering gender perspective education. In addition, it is necessary to analyze similar projects and to include students as part of the working group [15]. Finally, it is very important that the executive direction of the Engineering School gets involved for the success of the program because the gender perspective could be integrated through activities like the welcome day.

Finally, Table I summarizes all the activities directed to students at every education stage. It shows the age range,

TABLE I
ACTIVITIES DIRECTED TO STUDENTS.

	Girls' Day	WikInformática	A female Engineer in Every School	Mentoring
First Edition	2008	2015	2016	2018
Current edition	10^{th}	5^{th}	4^{th}	2^{nd}
Site	Schools of Engineering	Higher Education Centers	Primary School Centers	Schools of Engineering
Age Range	14-18	12-18	6-12	> 18
Budget last edition (€)	2000	13250	2000	1500
Approx. Volunteers last edition	20	50	100	10
Approx. Students last edition	500	700	3000	50

budged, volunteers, and number of participants of the most recent edition. This can be an indicator of their impact and resources employed. In addition, most of the activities appear in mean mass, social networks and research publications.

IV. ACTIONS TO PROFESSIONALS

According to the 2018 figures from the European Commission [16], tertiary educated women are still a minority in science and engineering occupations in most countries of Europe. In particular, they are 35 % of grade C academic staff, 28 % of grade B and 15 % of grade A. Then, actions directed to advance the professional career together with the retention of women are of great interest.

Non-for-profit organizations as AMIT [17] (Association of Women in Research and Technology) have been working on promoting the full incorporation of women in science and technology. Among its different territorial nodes in Spain, AMIT members interact with society to promote change. Activities include the organization of events to highlight the gender gap, support actions to reduce the gender gap, encourage women's promotion or favor professional networks.

Moreover, among different professional associations, special working groups exist for the promotion of women in engineering such as the IEEE WiE in the IEEE (Institute of Electrical and Electronics Engineers) [18].

Among the many actions carried out by these groups to advance the careers of women in the professional work, there are several ones that are worth citing:

- Mentoring among professionals. Women professionals in a more advanced stage of their careers provide help to younger ones
- Organization of focused training oriented to women. For example, leadership courses with the objective of providing tools for advancement. In other cases, short courses or sessions oriented to provide resources to generate positive change
- Networking. By getting to know female peers, stronger bonds can be built and cooperation can be started. It is important to be able to share time and get to know each other in order to trigger future possible common projects
- Positive actions. EU Commission, as an example, takes gender equality as an important factor in the access to financial resources for innovation and research projects. In Spain, at professional level at University, gender parity is encouraged in examination committees.

Therefore, being enrolled with an organization with such type of initiatives have a significant value specially for a women with a job in STEM.

V. CONCLUSIONS

Present statistics or a simple look around show that we are far from gender equality particularly in STEM. Because of the "leaky pipeline", the unbalance is stressed at the working-place. The participation of women in technology is a question of right and the balance but also conducts to quality innovation due to diversity. Consequently, as gender equality is mandatory not only to economic development of the world, but to progress to cover global social needs, this is part of the agenda of important worldwide organizations.

As a result, many isolated activities have been performed in the recent years in order to promote the recognition of women in engineering. Most of them have been focused to the increase of vocations at high school and just a few ones at primary education. Little is known about their impact. Our experience and research works suggest that emphasis must be set at the primary school and teachers must be involved.

Besides, different mentoring programs at universities must be analyzed in order to design effective actions directed to all the community. University has to become a safe environment to help the learning process and personal development for male and female students. Having a gender perspective could prevent discrimination and the enhancement of diversity at the different academic activities.

Nowadays, women at the working-place face the worst statistics according to abandon and the occupation of positions of responsibility. Studies suggest that women's hope, optimism and core identity impacts work engagement. Therefore, it is very important that women perceive equality with their male counterparts. Associations that highlight the gender gap and promote actions to reserve the situation are very important.

Finally, authors would like to note that despite the support for the different activities, the main effort is still made by women volunteers. Future actions must be leader-shipped by governments and male counterparts must increase their participation. Both are key part for breaking the gender gap. Going together, excellence in Engineering for a better society will be really advanced.

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