Providing female role models in STEM higher education careers, a teaching experience

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***Abstract*— Women are still underrepresented in science, technology, engineering, and mathematics (STEM) careers, not only in Spain but also in many Western and European countries. Female role models are key to broadening participation in STEM fields, which is why our teaching innovation group has been involved in initiatives to promote female vocations in STEM aimed at non-university education. In this paper we present different initiatives to provide female references to the students of the bachelor's degree in Mathematics, Chemical Engineering, and master's degree in computer vision. With these initiatives we aim to contribute to empowering female students of these degrees and to break with the sexist stereotypes that persist in our society. The activities have been well received by the students so we will continue with them in the next courses.**

Keywords*— *STEM, gender perspective, higher education, SDG 5

I. Introduction

In Spain, women are under-represented in STEM careers and over-represented in health and care-related fields [1]. To combat this gender gap, which is detrimental to women and to society [2], numerous initiatives have been carried out to provide female role models in STEM for students [3]-[5]. Most of these initiatives have been carried out in the field of primary, or secondary education and are of great importance to change the sexist stereotypes that persist in our society, and which affect the choice of university careers [1]. But we must not forget that at university level our female students also need role models, because as Patricia Fara points out "To ensure true equality of opportunity, modern scientific women must make themselves heard and make themselves seen. We need to hang female portraits on corridor walls, make sure that student reading lists include papers by women and stand up at the lectern to deliver keynote addresses" (https://unherd.com/2018/11/women-erased-history/).

In our teaching innovation group named "Active methodologies in science teaching" in the University of Santiago de Compostela (USC) in Spain, we believe that to achieve the goal 5 (gender equality) of the Sustainable Development Goals (SDGs), which aims to empower women and girls, it is important to carry out actions in both primary, secondary and university education. Therefore, we have collaborated with initiatives such as "Unha enxeñeira ou científica en cada cole" (https://unhaencadacole.gal/) developed in Galician language, which English translation will be "One woman engineering or scientist in each primary school". It aims to provide female references in the technical scientific field in the of Galicia's schools. In this program, different researchers from STEM careers at the USC designed and taught scientific workshops in primary schools. In the last two years, the activity was developed online due to the COVID-19 pandemic restrictions. As a one-off activity, our research center CITIUS has held a series of conferences/workshops for elementary and secondary schools to commemorate the day of girls in Information and Communication Technology (ICT) in 2021 [6]. In these activities participated more than 1000 students from the Galician region (Spain). Other non-structured conferences were taught in the secondary schools by invitation. In addition, we have participated in training courses for primary and secondary school teachers. (https://www.edu.xunta.gal/centros/cafi/aulavirtual/course/info.php?id=1069&lang=es)

In the high school education, we conducted various activities to integrate the gender perspective in the teaching of degree and master courses. These experiences have been recognized with awards from our university in 2018 and 2021 for the introduction of the gender perspective in teaching courses in the physics and the artificial intelligence fields (https://www.usc.gal/gl/servizos/oix/modules/news/news_0105.html).

Although, in recent years, there has been a boost to introduce the gender perspective in university teaching in Spain, for example, with the guides published by the Xarxa Vives d'Universitats [7] or Grial group [8], the "publications on non-sexist university teaching are scarce in any language and, more specifically, in Spanish" [9]. Merma-Molina also achieves this conclusion [10], in a review of the scientific literature on the integration of SDG 5 in university teaching in Spain. In this paper, we describe our experience in the introduction of gender perspective in the high education during recent years to increase the number of didactic experiences, which help to make women visible in the university environment. Our experiences were developed in the chemical engineering, mathematics, and physics degrees and in the master of computer vision. In the following sections, we describe each of the experiences accompanied by comments about the results obtained. Finally, section IV summarizes the conclusions and future work.

II. Chemical Engineering

Physics is a mandatory course, which is taught in the first year of the Chemical Engineering degree with 60-65 students enrolled each year (58,31% of men and 41,69% of women in 2019-29) [11]. Along the last years, different activities have been conducted to make women's contributions to this discipline more visible. On one hand, the female contributions of both historical figures and current scientists have been made visible in the course slides and bibliography and in the

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virtual classroom. We try to make students aware that many female scientists are very relevant in topics such as the energy transition and in the fight against climate change [12]. On other hand, the teacher coordinated the publication of female biographies by the students in Wikipedia, the Galician version of this online encyclopedia [13]. Both activities are detailed in the following subsections.

A. Physics virtual classroom

This subject has a Moodle virtual classroom, which allows to link videos, pictures, or interviews with women scientists, showing a different point of view of the science that the one usually shown by the textbooks.

Fig 1. Virtual Classroom of Physics course in Chemical Engineering degree Source: Self-made

In this virtual classroom we have also included a photograph of a female scientist or engineer in each course theme. For example, a picture of physicist Hendrika Johanna van Leeuwen was included in the Magnetic field and force theme along with a brief account of her contribution to magnetism. Figure 1 shows a screenshot of the virtual classroom.

B. Wikipedia

In this activity, the course students were asked to write and publish a biographical profile of a woman scientist or engineer. This activity has two phases: in the first one, conducted through the workshop tool, the students will have to write the biography, which will be corrected by a classmate [13]. In the second phase, the students must attend a course where an expert explains how to publish the biography on Wikipedia and make the publication, correcting the mistakes detected by their classmates. Participation is voluntary for students, but they can get points for their participation to add to the final score. Also, Wikipedia-editing skills are important "for professional development: exercising these skills is an opportunity to assimilate and communicate complex information from multiple sources, contextualize scientific research, structure a discussion, add citations and references and share expertise with the broader public" [14].

In the 2019-20 academic year, the students participated in the joint elaboration of the biographical profiles of the following five women: Susan Solomon, Tebello Nyokong, Margaret Hutchinson Rousseau, Sandra Myrna Díaz and Alice Larkin. This year each student elaborated a biographical profile, and that has allowed the publication of 50 new biographies [15], showed in Figure 2.

Fig 2. Wikipedia biographies for the Physics course of Chemical Engineering degree. Source: Self-made

Throughout these years I have seen that both boys and girls participate in this voluntary activity, and that it is well appreciated by both. We believe that the participation of boys is fundamental because it is necessary that they also have female role models in science and engineering to help us change this androcentric vision that still survives in our society.

III. Mathematics and Physics

We developed different activities in the first-year programming course of the mathematics and physics degrees with the aim of making the work of women in programming more visible and promoting university education in gender equality. Both courses are mandatory for both degrees. Some common activities to manage the students in the course are: 1) the use of inclusive language in oral and written narrative, because it is very important in Latin languages for which the masculine construction is used to designate both sexes; 2) the use of programming examples with neutral non-sexist content; 3) highlight female authors in the bibliography; or 4) the use of teaching methodologies that include equally all ways of learning, for example, managing cooperative learning activities which take into account the gender dimension

All the static material of the programming courses are available in open web pages in the Galician language. The mathematics programming course is called *Informática* [16], with approximately 130 students enrolled each year, 45,03% women and 54,97% men in 2019-29 [11]. The Physics programming course is called *Informática para científic@s* [17], with approximately 120 students enrolled each year (22,73% women and 77,27% men in 2019-29) [11]. In both courses, we have included one slide in each unit dedicated to an important programming woman. Figure 3 shows the slide dedicated to Ada Lovelace, the mother of the programming field. We are also building an alphabet of women in programming from all times to make visible and value the work of women in programming. The alphabet is maintained by the teaching staff from the classroom debates, either face-to-face in the lab class or through the subject's private forums for the students in Moodle virtual classrooms. The alphabet for both programming courses can be seen in [16]-[17].

In the Mathematics degree, the teaching staff developed a cooperative learning activity based on the Teams - Games - Tournament [18] in their theoretical classes. This is an

alternative didactic methodology based on the group collaboration to achieve common goals. In the first half of semester, we explain the theoretical concepts of Fortran programming language using master classes. In the second one, the Matlab programming language is learned using work team collaboration. The final work teams are built by the teaching staff using the gender and academic performance dimensions, making sure that each group has a man and a woman as leaders. Normally we set 15-16 groups of 7-8 students each one, adding more than 100 students divided into 2 classes. The detailed description of the activity is out of the score of this paper. Although this activity is volunteer for the students, each student can add some points of the team score to his/her final grade. After the activity, the student´s perception was evaluated by a form that they filled voluntary (88 students, 49 men and 39 women). Regarding the statements: 1) "I understand the topic better", the 50% of men and 64% women agreed with the statement; 2) "I have more motivation to study", the 53% and 56% of men and women respectively agreed; and 3) "I prefer normal teacher classes to classes with collaborative work", the 28% of men and the 26% of women agreed. These results were obtained in the 2018-19 academic year due to the activity could not been developed during the COVID pandemic. The main conclusion is that the student's perception was good, especially for the female students.

Fig 3. Ada Lovelace slide in Informatica Course of the Mathematics degree. Source: Self-made

Although a statistical evaluation of the improvements of these activities in the female students scores is very difficult, we subjectively perceive that all these active methodologies make female students feel more motivated and happier in the development of the classroom. Therefore, we deduce that this has a positive effect on their learning and their final grades. Some female students feel that their way of learning is considered and hence many female students achieved the maximum punctuation in the courses.

IV. MASTER'S DEGREE IN COMPUTER VISION

The presence of women in the Information and Communication Technology (ICT) field is lower than 20%, both in the presence of female students in higher education studies of ICT and in the professional sector [19]. Regarding artificial intelligence, it is known that systems based on machine learning can be harmful for the citizen and, in special, for women [20]. The machine learning course of this master (see the open web page of the course for static content [21]) has approximately 15 students enrolled each year (25% women and 75% men). The master is taught between the countries Spain and Portugal. So, the courses are taught online in English, a language less sexist than the Latin languages. In the 2019-20 academic year, we developed an experience introducing embedded ethics activities with gender perspective in order to make students aware of the development of these intelligent systems in their professional future [22]. The activity consisted of discussing through the private forum of the virtual classroom issues related to discrimination in intelligent systems based on examples. As we verified in the classroom, the women are normally more sensible than men to issues related to ethics in artificial intelligence. So, making visible the women research work and activities, we are debating about the ethics in artificial intelligence. In this academic year, we are also building an alphabet of female researchers in artificial intelligence, which can be seen in [21]. Figure 4 shows a screenshot of the web page.

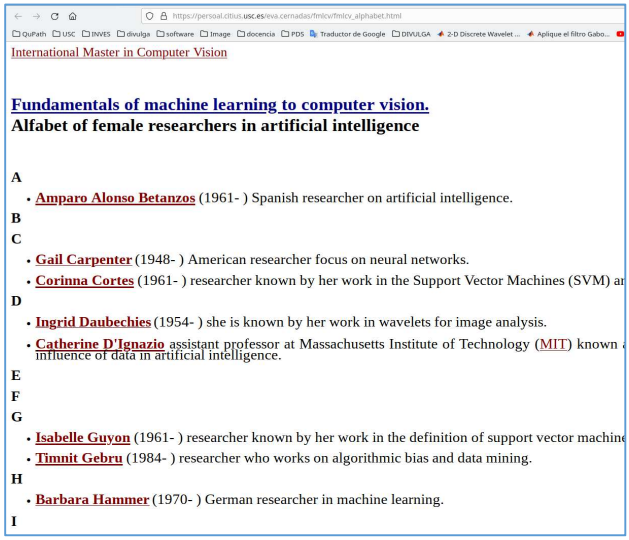

Fig 4. Alphabet of female researchers in AI in the Fundamentals of Machine Learning for Computer Vision course. Source: Self-made

V. CONCLUSIONS

We presented different didactic initiatives in higher education of STEM careers to provide female role models for students. These activities focused on visualizing and highlighting the women's work in the field of Physics, Chemical Engineering, Programming and Artificial Intelligence, a work that is normally hidden in textbooks. Although a detailed description is out of the scope of this paper, other activities try to develop learning environments which highlight the way female students learn. This configures other ways of team working, which also enriches the traditional masculine roles. Our subjective observation is that all these activities give the students a point of view different that the one shown by the textbook, mainstream media, films and so on, and they develop critical thinking in relation to gender roles in science and engineering. These individual didactic experiences try to go one step ahead to reduce the gender gap in the STEM degrees and masters, and break with the sexist stereotypes in our society. Although these experiences are very encouraging, only a limited part of the university students is affected by them. However, the experiences described also pretend influence the rest of the

teaching staff in STEM disciplines and to become a reference for them to change teaching habits. Another objective is to improve the women's learning through the management of inclusive and participatory educational environments for female students, fostering their self-esteem and confidence in their abilities, i.e., developing gender equality skills by practicing in the classroom.

Nevertheless, we believe that a further social progress in gender equality requires the implementation of active institutional policies, for example coordinated by each university or by the CRUE (the Spanish Conference of Universities Rectors) in Spain, which should not only promote new teaching methodologies at the university, but also should evaluate the advances of the didactic initiatives implemented. Of course, the gender equality problem in STEM disciplines needs a global vision, in which high educational didactic initiatives must be complemented by outreach activities, aimed at changing gender stereotypes in primary and secondary education and in our society in general, to reduce the current gender imbalance in STEM degrees.

ACKNOWLEDGMENT

This research has received financial support from the Xunta de Galicia, acreditation 2019-2023 ED431G-2019/04 and the European Union (European Regional Development Fund-ERDF).

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