Diversity and Inclusion in Engineering Education: Looking Through the Gender Question

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***Abstract*—The STEM (Science, Technology, Engineering and Mathematics) field in general, and Engineering, suffer from a lack of diversity. Yet there is growing evidence that more diverse organizations are more successful and effective. There is also a global shortage of STEM and engineering skills that can be tackled by addressing the lack of diversity in the field. One obvious way to view this problem is by looking at gender. Women make up 50% of the population, but in Engineering the number of female students and professionals is clearly less than this, often around 10 – 25% in many parts of the world. This underrepresentation of women leads us to think about other groups that are underrepresented in Engineering; these include Black, Asian and Minority Ethnic (BAME) and those from socially deprived backgrounds. This paper examines a number of approaches to support diversity and inclusion to encourage a greater uptake of engineering by underrepresented groups and to retain people in the sector.**

Keywords—Diversity; Inclusion; Engineering Education;

I. INTRODUCTION

Diversity and inclusion are two distinct subjects that should work together, and these subjects appears around the word with many different characteristics. For Engineering, diversity is connected to attracting students and professionals to this field to ensure that engineering has a similar percentage of representation from different areas of society as the wider population. For this diverse group to work successfully, the different questions and needs of each individual arise and need to be treated appropriately. But without inclusion the few students and professionals that are attracted from the underrepresented groups feel pushed out, and can leave the field, as described in [1]. Furthermore, new students and professionals do not enter the field. One of the reasons is the lack of role models for these underrepresented groups, and the problem of underrepresentation continues.

One of the main underrepresented groups in Engineering is women. They represent around 50% of the population in any country, but their presence in Engineering, as students or professionals, is far less than this in most areas of the world. There are many studies that have examined the small number of women in Engineering. Balakrishnan and Low [2] studied the small number of female professionals in Engineering in Japan, and argue that this number could increase, benefiting the society with the country producing more professionals that understand the culture and questions of their country. Lee et al. [3] explored the perception of inclusion by students from underrepresented groups and found that different ethnic groups may experience inclusiveness differently. Universities should examine approaches which can make the institutional experience more positive for all students thus increasing the potential for good integration by students from different backgrounds and cultures.

The section II describes the gender question in STEM, the section III presents tools to deal with the inclusion of diverse groups, the section IV shows robotics as one valuable tool to integrate students. The last section compiles the conclusions of the presented material.

II. FEMALES AND GENDER

There have been several studies that have addressed the lack of females in STEM and particularly engineering. However, many of these have focused at secondary or university level. The issue starts much earlier and therefore the solutions need to be focused from an early age upwards. Padwick et al. [4] worked with children from age 7 to 15 years and showed that although boys and girls view the characteristics of a scientist as similar, for example hard working, clever and creative, they differ in how they view themselves with boys more aligned with their concept of a scientist than the girls. It is important to challenge these stereotypical perceptions of scientists and engineers so young people are able to see that they can be a scientist and engineer and that they are just 'people like me' [5]. One of the ways to achieve this is to integrate career messages and links into STEM and engineering interventions with young people so that they and their key influencers have a wider and more informed perception of a scientist and engineer and thus can see that it could be a potential career route for them. There is also the need to look at unconscious bias and ensure that society recognizes this and considers how to address it from preschool to university and the workplace.

Within the framework of gender inequality and the problems that occur in the low percentage of women interested in studying careers related to STEM, it is inevitable that this will spread and reach the next link, which is to reach working life, if there are few women interested in studying STEM, women will be underrepresented in the field of STEM in companies or as entrepreneurs in this sector.

To these circumstances, it is also added that the number of women who enter to work with time leave the profession in a greater number than men. In the technology industry, at the international level, female participation represents 25% of the total technical and engineering staff Ashcraft and Blithe [6]. In the European Union, of the 7 million people working in these areas, only 30% are women [7]

A research by Ashcraft and Blithe [6] in the United States shows the following displacements: Of the total number of women who leave their jobs in information and communications technology companies, 49% continue working in this field, but part of that a 22% in self-employment, 10% create their own company and 17% are located in government agencies or as NGOs. In the other hands, 51% leave it, of which 24% opt for jobs not related to technologies, 7% stay in the same company but in non-technical positions and 20% do not keep working. In relation to this last group, a study carried out in Great Britain detects that a significant number of technologists stop exercising after the birth of their first child and another group, also a substantive one is that of women between 40 and 50 years of age [6].

Why companies are advocating to change this paradigm, as the presence of women influence important advantages for companies, in this movement not only companies are involved, there are many agencies that provide information, which help us resolve these issues. A study conducted by Harvard Business Review reports organizations that have a more diverse and inclusive workforce tend to be more innovative and experience greater market growth than companies that do not embrace such a philosophy [8]. These data are confirmed by more studies, such as the study conducted by Digital agenda of the European Commission, where they affirm that if women held digital jobs as frequently as men, the European GDP (Gross domestic product) could be boosted annually by around € 9 billion. The information and communications Technology sector would benefit since organizations which are more inclusive of women in management achieve a 35% higher Return on Equity and 34% better total return to shareholders than other comparable organizations [9].

Today, most corporations in the ICT sector have incorporated some kind of diversity initiatives instead. In particular, the technology industry has faced numerous criticisms for its ostensibly predominantly and disproportionately male, white and Asian workforce. This has led companies to react and some leading companies in the sector to announce and carry out the commitment to hire more women, minorities, veterans and senior employees.

Exhibition of different projects for the improvement of diversity and inclusion in 6 large technology companies:

Linkedin, making use of its privileged position by the type of data that it manages within its social and professional network. They are drawing on user data to provide insight into gender equality across every industry and is researching gender differences in how users promote themselves in personal profiles [10].

Salesforce conducted a salary review of its 17,000 employees, making subsequent pay adjustments where deemed appropriate, and has invested nearly $3 million to eliminate statistically significant differences in pay [11].

Intel through the "Diversity at intel" has been publicly and transparently revealing years of diversity data in its company, and the actions it carries out to reach the goal of gender parity in the year 2020 [12]. Other program is "Intel She Will Connect", focus on two key problems, one through camps in the U.S. middle school inspiring girls to become technology creators and innovators and another goal is to connect more women to the Internet and to basic technology skills so they can access information and new economic and social opportunities.

Google has created a platform, https://diversity.google/, where as Intel shares the progress made in diversity and inclusion within the company, have launched processes such as Google employees of 90 offices in 42 countries handling more than 30 projects through a program that allows employees to devote 20% of their work time to diversity efforts at Google [13].

Microsoft with "Global Diversion and Inclusion", adds to the good practices adopted by many companies, highlights the need to join forces to increase diversity are inclusion in the company, It makes transparent about workforce demographics and showed the different programs created for their employees and another series of programs for the community external to Microsoft, programs like DigiGirlz gives high school girls the opportunity to learn about careers in technology, connect with

Microsoft employees , and participate in hands-on computer and technology workshops [14].

IBM has a long history in diversity and inclusion processes, they have been creating meaningful roles for female employees since the 1930s. Currently one of the opportune programs offered is IBM's career re-entry program, Which is 12 weeks internship program working on real projects with a senior-level mentors, Eligibility for this program is that candidates must be 2 or more years out of work in the field of technology, taking into account that the career abandoned by women is a notable percentage, this is a timely opportunity to return to the labor market [15].

III. TOOLS FOR INCLUSION

Some studies have investigated the interest and motivation of students to study and pursue careers in STEM and Engineering. Blázquez et al [16] investigated the interest of students to Engineering in Spain and show that 30% of the students 'at the age' to start an undergraduate study are not qualified to enter the university. If the number of students interested in Engineering or STEM decreases, this is a strong warning that needs to be addressed. New generations are born with access to technology that was unthinkable to previous generations, but if they are not taking up STEM subjects at school, this needs to be addressed to ensure there is a future pipeline of diverse young people entering the STEM area to meet future demand for skills and jobs.

The question about the decrease of the number of students that are attracted to STEM leads to another question: Are appropriate tools being developed to help attract new students into the STEM area and are these new tools being used effectively to provide the required support to students, particularly those with special needs, that could specifically benefit from these technologies.

Some fields in STEM are connected to create a bridge between the user and the technology and can therefore address the question of inclusion. In Computing, one such field is Human-Computer Interaction (HCI). This is present in many undergraduate computer science courses and can be used to develop an awareness in students of how to give access to users with special needs. Palan et al. [17] present the results from their study that looked at how undergraduate students can be developed to practice 'inclusive thinking' and explore how technology can be made accessible to users with a range of disabilities.

There are many groups that are underrepresented in university more generally. One of these in Europe and USA is BAME. Some of this group have been part of wider society for a long time such as the African Americans in USA. McGee and Bentley [18] describe the women that are African American, and the challenges that they face to build an academic career, where even the most successful professionals or students can be in a position that they are not able to execute or fulfil to their best ability due to the wider university environment in which they are working. Other groups are newer to a specific country or region, but they should also be welcomed and integrated into the wider society so that they are able to enter university and develop their skills, as described in [19], which uses mixed reality to help integrate international students into the university community.

One challenging question for inclusion are the students with special needs. MOOCS (Massive Open Online Courses) can be useful and important tools to help these students learn. One example is the study by Królak et al. [20] that examines the issue of accessibility for blind students. These students can often find it difficult to locate a button (especially if there's no label) or stop a video that starts automatically with the auto play. Hawley et al. [21] explores the experience of students that belong to two groups at the same time, namely underrepresented race/ethnical groups and students with physical disabilities. These students need special support during their undergraduate studies and this research also indicates that more students from these groups could enter university if they had the appropriate support during junior and high school.

The question of inclusion of students with special needs also applies to students with intellectual disabilities. Buehler et al. [22] focused on students with intellectual disabilities, preparing them, with a post-secondary course, to work with 3D printing in a technical field. These students were able to work closely with other Engineers and STEM professionals in a productive way. A neurodiverse team of students, where some of them are neurotypical and/or have autism, can work together as described in the study by Zolyomi et al. [23], with appropriated technological tools.

IV. ROBOTICS AS AN INCLUSIVE TOOL

In the previous section some computational tools to integration was cited, and in this section, it is described a simple robotic experiment that can be used to integrate the students in a team work, developing their capacity to deal with other students with different background and skills.

Scientific and technological progress is one of the major challenges facing the world community in this new millennium. However, when speaking of women and under-represented groups, the immediate reaction is to indicate their low presence in their development. This is a worrying fact that should not go unnoticed, since if we go deeper into the studies of science, engineering and computer science that is what we are currently dealing with, we realize the need for young people in these groups to learn technological skills, such as computer thinking competence; because they are also responsible for the generation and consumption of the technology present in today's society, having an important role in the process of creating and supervising them, although they are sometimes ignored. Therefore, low-cost tools for educational robotics in the context of STEM can be used as a thread to promote inclusion and diversity in society.

Educational robotics is a means of learning in which people participate with the motivation to design and build their own creations. These creations are formed by different types of materials, sensors and actuators, and controlled by an electronic device that is usually a microcontroller or a microprocessor. During the creation process, different prototypes and/or simulations may arise.

The robotics-based pedagogical method promotes guided discovery and inductive learning based on constructionism. Cognitive theory is used, with constructivist processes giving importance to experimentation methodology based on trial and error as a phase of the learning process. The main cognitive characteristics of educational robotics are:

- Integration of different areas of knowledge,
- the passage from the concrete to the abstract is favored.
- use of different languages,
- development of systemic and systematic thinking,
- construction and testing,
- learning and use of the scientific process and
- creating a playful and heuristic learning environment.

Educational robotics also works on aspects such as teamwork, leadership, learning from mistakes and entrepreneurship. In addition, robotics provides students with discipline and rigor. Another key to the insertion of robotics in schools is its multidisciplinary, that is, working robotics is easy to combine tasks related to STEM. The aim of educational robotics is not to prepare young people to build robots as a way of making a living. Nor is it preparing them to work in a factory that uses robots. It is a methodology and a series of didactic tools to train and transmit in a practical way some attitudinal aspects, such as those listed above.

The robotics is being used as the modernization and improvement for most of processes. This occurs as result of robots can be easily integrated within the current industrial processes [24]. Robots represent a promising educational tool.

Some examples of cost-effective educational tools are:

- Scratch and App Inventor: these tools are very easy to be used either by faculty and by students because students can acquire programming skills in an easy way by Scratch and App Inventor are based on building blocks programming. This different characteristic allows students aged from 6 to 10 years to get into programming without language barriers. On the other hand, neither Scratch or App Inventor allow a physical interaction between what is programmed and the students. Finally, the cost associated to these tools is not a problem because both can be used for free.
- Crumble: it is an easy-to-use programmable controller. Its programming interface uses a block programming language which eases its use by children aged from 9 to 14. Educational robotics can be implemented easily with it due to the board connectors. Motors and servos can be managed by Crumble. Additionally, different sensors can be connected to it such as ultrasound distance sensor, infrared distance sensor and line detector sensor. Furthermore, Crumble is able to manage up to 32 RGB (Red, Green and Blue) LEDs (Light Emitter Diodes) independently and using 16 bits' color resolution.
- Arduino and PICAXE: these tools are programmable too, but a textual programming language is needed. This is a disadvantage for students aged below 14 years because it is very hard for them. As an advantage against Scratch and App Inventor, Arduino and PICAXE integrates mechatronics and programming at a reduced cost. Additionally, these tools provide a wide range of activities to be carried out. Although, there are not much official, categorized and accessible documentation related to STEM education. A basic Arduino board can be acquired by 20 €. A PICAXE initiation kit costs about 17 €.

Currently, there are several options to introduce educational robotics. [25] presents Crumble as a tool which can be used with the aim of deploying STEM knowledges at home joining adults and children. Furthermore, [26] explains how to use Scratch to introduce students to robotics, enabling Scratch to work on the basics of programming and introduce students to skills such as systems thinking, programming mindset, active learning, mathematics, science, judgement and decision making, good communication, technology design, complex problem solving and persistence. Additionally, non-Computer Science oriented curricula can be scaled using collaborative scenarios to enhance teaching–learning programming [27].

V. CONCLUSIONS

In this work was highlighted the lack of diversity in STEM. This work started with the very well noticed question of the small number of women in this field and developed the question to other underrepresented groups in STEM and Engineering. After the discussion, robotics was presented as a valuable tool to integrate the students, since in the school the students can be more easily motivated with the new technologies that starting to become part of their life.

Attracting, and supporting, a more diverse group of students can have as a result a more diverse group of professionals, and this can lead to recognize more easily the questions that the society can be beneficiated with STEM and Engineering knowledge.

In a globalized world is also an important skill for the students to learn how to work with different professionals from different places with distinct skills and needs.

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