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Educational Robotics for All: Gender, Diversity, and Inclusion in STEAM

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***Abstract*—The pedagogy of science, technology, engineering, arts, and mathematics (STEAM) can be easily developed by using robotics and computational thinking tools. Also, inclusion and integration of diverse groups of students can be promoted using these tools. Today we can find many tools for teaching robotics. This kind of tools allow us to promote innovation and motivation of students. In this way, students will be able to work during the learning process in an innovative and motivating way. Since it is increasingly common to find robots in our daily lives, it is important to integrate robots into education as well. There are already cooking robots, autonomous cars, vacuum cleaner robots in houses and gardens, or prostheses. This paper describes a course focused on a combination of teaching methodologies, educational robotics tools, and a student learning management methodology, all within an inclusive framework to strengthen the presence of women and other under-represented groups in engineering.**

Keywords— diversity, inclusion, educational robotics, instrumentation, STEAM.

I. Introduction

The topic of gender imbalance and debarment is different in each, but we still find, in any country, different ways of gender discrimination, gender stereotypes, and an unfair distribution of power between individuals - women, men, girls, and boys. Not only does this type of discrimination exist, but there is also exclusion based on individuals' groups such as race, ethnicity, class, language, ability, gender identity, and sexual orientation. We recognize that people have multiple identities that shape their experiences and believe that addressing gender inequality can be strengthened by examining how these identities are intertwined; this knowledge can then inform programmers and advocacy. It is well known that gender inequality intensifies the negative effects of other forms of exclusion, leading to a distinct and, in many cases, worse environment for women and girls [1]. Among excluded groups, girls often face the greatest obstacles to exercising their rights and, therefore, gender equality and girls' rights must become a clear concern for education.

Educational robotics is one resource to promote inclusion, interaction, interdisciplinarity, problem solving, and collaborative work. Teaching and learning that incorporates these characteristics has the potential to achieve important skills in a motivating, dynamic, and enjoyable way that can build confidence and self-esteem.

Children today are digital natives and therefore education must be adapted to this circumstance. One way to do this is through robotics, an interdisciplinary subject in which mathematical and scientific concepts are worked on as well as concentration and creativity.

Robotics is an interdisciplinary method in which the areas of Mathematics, Technology, Science and Engineering are worked on. Its cross-cutting nature enables children to also develop logical thinking, imagination and linguistics.

The benefits of robotics are not only evident - learning to program and becoming familiar with the technology - but it also allows for the development of other skills and for cross-functional learning.

- Teamwork: many of the challenges posed must be solved by working together. This contributes to socialization and collaboration since only by coordinating and sharing knowledge/skills will they be able to solve problems.
- Leadership and confidence: as more complex tests are carried out, confidence in oneself and one's abilities grows. This self-esteem is complemented by tolerance to frustration when they fail in doing what is set out at first.
- Promotion of entrepreneurship: children develop new skills through experimentation and trial/error. That is why they are eager to innovate, to think independently and, consequently, to undertake their own projects.
- Logical thinking: robotics promotes logic and reasoning so, indirectly, it is also valid to work on philosophical thinking.
- Psychomotricity: the assembly necessary to fit the pieces of the projects/robots requires psychomotricity and coordination work.
- Creativity: imagination is always present as students must design different models, robots, constructions...
- Curiosity: discovering how a model is made or how a robot can move arouses curiosity and interest in learning new things. As opposed to the traditional system of repetition, the child himself is the protagonist, having to make his own material using his own resources.
- Concentration: perfect for the most restless children and those who find it difficult to focus.
- Mathematics: improvement in problem solving, mathematical operations and reasoning.

The educational innovation demanded by today's society necessarily involves the gradual introduction of ICT-related subjects in which students are no longer mere spectators of the teachers and can design and build their own projects.

In this paper, we present an initiative in this direction, offering a completely free Massive Open Online Course (MOOC) on educational robotics that emphasizes the need for inclusion in STEAM education.

II. State of the Art

Educational inclusion is understood as a set of actions and measures aimed at identifying and overcoming barriers to learning and participation of all students, as well as promoting the educational progress of all [2]. Inclusion should consider different learner strengths, preferences, motivations and interests, in addition to their personal, social, economic, cultural, and linguistic situations. This must be accomplished without equating difference with inferiority so that all students can fulfill their potential to the best of their abilities.

For the case of gender, an especially important bias is detected in the field of software engineering towards the male population. As one example, Izquierdo et al. [3]

identified multiple studies indicating gender imbalance in the open source environment.

There are also studies demonstrating a global shortage of knowledge in Science, Technology, Engineering and Mathematics (STEM) areas that can be addressed by diversifying the field [4]. In addition, many studies have analyzed the perception of gender in the field of engineering, such as the work described by the authors in [5]. As an example, a study on MOOC registrations across twelve MOOC providers analyzed the important disparities in MOOC enrolment by gender across these platforms [6]. This gender gap is even more evident in developing regions, more specifically, previous work analyzed this issue with Arab learners in edX and Edraak (an Arabic MOOC provider) environments [7]. They found that the gender gap was more acute in the global setting than in the regional setting of Edraak with courses in Arabic.

In recent years, Science, Technology, Engineering, Arts and Mathematics (STEAM) has become part of the training and education offered in centers where students have a leading role, sometimes taking advantage of this to work on equality plans and to promote women in science. Complex problems are worked on by students from different backgrounds and different disciplines resulting in creative and innovative solutions using the possible technologies [8]. These types of projects and educational experiences help to minimize the digital gap and social segregation and increase access to technology [12].

Diversity has always been present in schools, in educational communities, and in all activities, providing an environment where diversity is the natural thing. Despite this, there are many places where diversity is not the norm. In recent years, it has gained prominence in educational projects and teaching practices, due to a demand for visibility by various institutions and above all, by society in general. Some examples can be found in [15].

These reasons all led to the decision to design a MOOC that promotes diversity and inclusion, specifically related to gender, in STEAM using educational robotics.

III. MOOC INTRODUCTION

A valuable tool for developing the pedagogy of STEAM is educational robotics. Educational robotics is also valuable for promoting students in an inclusive and integrating way. We can find lots of robotics teaching tools to get advantage from. This kind of tools can be easily used by students during the learning process to promote innovation and motivation. It is important to integrate them into our daily lives because robots are increasingly common in our world. This course focuses on a combination of teaching methodologies, educational robotics tools, and a student learning management methodology, all within an inclusive framework to strengthen the presence of women and other under-represented groups in engineering.

For the development of the MOOC content, we have taken advantage of experiences related to four tools for working STEAM and educational robotics: Electronic Instrumentation together with tools as Scratch, Crumble and Arduino microcontroller.

Electronic Instrumentation is the science and technology of measurement. Instruments that measure non-electrical magnitudes use sensors that provide electrical signals from other magnitudes (mechanical, thermal, magnetic, chemical, radiation, etc.). Therefore, the first module in this area is dedicated to the Electronic Instrumentation, drawing on the experiences described in [19].

The use of a virtual tool can be a positive first contact with computational thinking and educational robotics, therefore Scratch has been chosen for this purpose (https://scratch.mit.edu/). The results of the experiences indicated in [21] have been built on and integrated as part of the course. Figure 1 depicts the Interface Development Environment (IDE) of the Scratch tool.

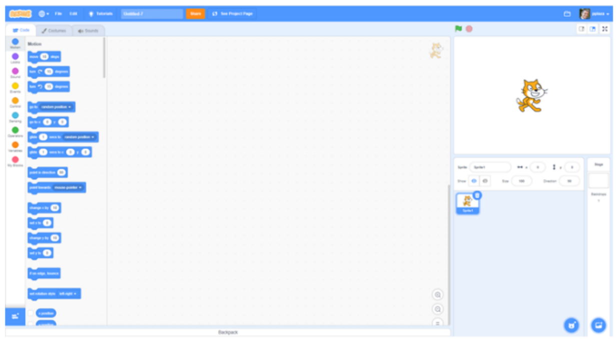

Fig. 1. Interface example of Scratch tool.

In a next step, the use of a tool that allows simple programming and simple hardware connections is then used so that students can experiment with the hardware elements progressively. Crumble was chosen because it allows instructors to prepare educational scenarios based on STEAM and educational robotics (https://redfernelectronics.co.uk/), as detailed in [25]. Figure 2 includes the Crumble IDE (in the top) and the Crumble development board (in the bottom).

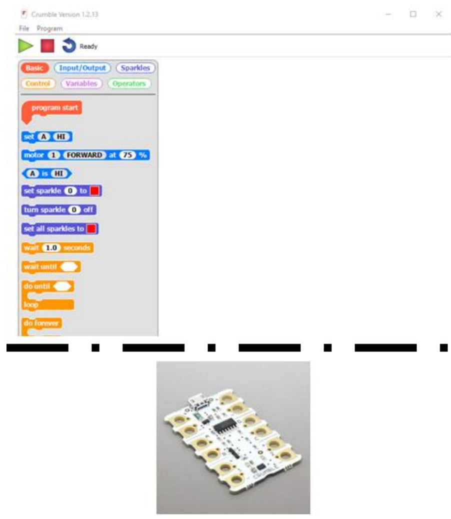

Fig. 2. Interface and hardware examples of Crumble tool.

Finally, the Arduino microcontroller, which emerged as a project for students at the Ivrea Institute (Italy), is used because it is a free hardware platform consisting of a board with a microprocessor and a development environment (https://www.arduino.cc/). It has also been chosen because it allows students to develop more complex applications with more functionalities than those that can be achieved with the two tools mentioned above. Some application examples are detailed in [28], and these have been used as a reference. Figure 3 shows the Arduino IDE (in the top) and the Arduino development board (in the bottom).

Fig. 3. Interface and board examples of Arduino tool.

One of goals for this MOOC is to provide a set of tools which allow to build learning scenarios with different tools. This strategy has been made satisfactorily along the works [31].

There are two types of course objectives in the MOOC: (1) what the student will learn about; and (2) what the student will learn how to do.

For the first set of course objectives, the student will learn about:

- The value and relevance of including women and other underrepresented groups in engineering education and STEAM careers.
- Active teaching methods and project-based learning focused on robotics and related STEAM activities.
- The relevance of the Electronic Instrumentation for Robotics.
- Robotics tools, including the user interface environments of Scratch, Crumble, and Arduino.
- Concepts that facilitate the deployment of robotics tools in an educational environment.
- Methods for student learning management.

For the second set of course objectives, the student will learn how to:

- Create simple robotics applications using a variety of instruments.
- Integrate robotics and related STEAM activities into the classroom or online instruction.
- Manage this same instruction to present concepts effectively, offer constructive feedback, monitor student progress, and motivate students from underrepresented populations.

In the following sections, the different topics, target audience, and syllabus related to these objectives are discussed in more detail.

IV. MOOC Topics and Content

The MOOC consists of a total of eight modules:

- Presentation of and Introduction to the Course.
- Special Interventions: Success stories and leadership in the STEAM area.
- Gender and STEAM: Active methodologies and project-based learning used in STEAM and educational robotics.
- Electronic Instrumentation in Learning Environments.
- Educational Robotics Tools: Scratch, Crumble, and Arduino tools.
- Deploying Educational Content with Scratch, Crumble, and Arduino.
- Student Learning Management Methodologies.
- Lessons Learned and Conclusions.

The content areas are: Science, Teaching, Education, Engineering, Mathematics, Teaching Methodologies, Student Management Methodology, Women and Inclusion, Programming, Electronic Instrumentation, Robotics, STEAM, Technology. No previous knowledge is required.

The target audience of the course is people without previous experience in robotics who want to get into educational robotics and use what they have learnt at home, in their institution, or as part of their research. It may also be of interest to people who want to be more inclusive and promote more women in STEAM fields.

V. MOOC Syllabus

Throughout the *Presentation of and Introduction to the Course*, the content and topics are introduced. It is estimated that this requires a dedication of less than one hour by students.

The *Special Interventions* topic includes several interviews from women who have reached success in STEAM and leadership. It is estimated that this part will require less than one hour.

Next, during the topic *Gender and STEAM*, there is an introduction to gender, diversity, and inclusion in STEAM. Furthermore, this topic includes design through co-educational practices for STEAM and details of inclusive design and project-based learning in STEAM projects. Finally, the application of gender and value-sensitive design in STEAM projects is demonstrated. This should require an estimated dedication of four hours.

As part of the *Electronic Instrumentation in Learning Environments* topic, different types of instrumentation and sensors/transducers commonly used in the industry are discussed, This is followed by a look at how these can be integrated into the classroom and the elements users can employ to make applications in the context of STEAM and educational robotics. Once this topic is finished, it should be possible to make simple applications with any of the instrumentation dealt with throughout this topic. Students will need an estimated four hours to complete this module.

Within the content of the *Educational Robotics Tools* module, three tools are introduced. Firstly, the Scratch tool. In a second step, the Crumble tool. Finally, the Arduino tool. This is the student's first contact with these tools. Part of the topic describes the user interface environments and provides a series of elements that can be used to make applications in the context of STEAM and educational robotics. Once this topic is finished, it is possible to make simple applications with any of the three educational robotics tools. An estimated dedication of four hours is required for this topic.

Deploying Educational Content with Scratch, Crumble, and Arduino will teach students about the use of the previously presented tools - Scratch, Crumble, and Arduino. Throughout this topic, examples of educational applications created with Scratch, Crumble, and Arduino are shown. Examples of educational content display related to STEAM and educational robotics in the classroom are also described. At the end of this topic, it is possible to create educational content related to STEAM and educational robotics to be presented in the classroom. An estimated dedication of four hours is required for this topic.

The final main topic is focused on *Student Learning Management Methodologies.* This module details how to manage the learning process of students, how to manage the educational content deployed in the classroom, and how to improve the educational content already deployed, using the information acquired from the educational results. At the end of this topic it will be possible to manage the learning process of the students and to manage the educational contents and life cycle from one course to the next. It is estimated that this will take students four hours to complete.

At the end of the course, the *Lessons Learned and Conclusions* module addresses what was learned in this course and summarizes the conclusions. This requires an approximately two hours.

VI. MOOC MATERIALS AND ACTIVITIES

The first module includes a set of one document, one video, and one quiz. The other modules are built on a set of four documents, four videos, four activities, and three quizzes.

Each module lasts one week. At the start of each module, students take a pre-test to assess their existing knowledge on the topics. Towards the end of the module, a post-test is taken that contains similar questions to the pre-test, plus new desirable knowledge only obtained through the module. Additionally, learners are also asked about their satisfaction with the module and its topics.

Additionally, each module also includes a social activity that involves students sharing some of the results in Twitter using widely active hashtags related to education. The objective is engaging other social media users that care about gender, diversity, and inclusion issues in STEAM education. This way, the social phenomenon of the MOOC goes beyond the course participants, by inviting other interested individuals to participate.

The main content in each module are videos of about 10-15 minutes and short documents (typically less than five pages) that include the information presented in the video, plus recommended material to extend the information on the topic. Furthermore, as complementary materials, there are links to related open educational resources. As part of the activities, the students are expected to participate in forums by discussing three questions. Finally, the students are also challenged to build a learning community in which to share experiences and resources.

VII. CONCLUSIONS

This paper has presented the outline for a MOOC that promotes gender diversity and inclusion in STEAM using educational robotics. This MOOC employs an inclusive framework designed to be attractive to women and other underrepresented groups in STEAM.

As part of this provision, there is a plan to investigate how this type of learning allows students to achieve several important skills in a more motivating, dynamic, and enjoyable way, thus increasing student confidence and self-esteem. Hence, the presented MOOC design is intended to answer several questions to tackle and investigate the inclusion problem:

- How do students react cognitively and emotionally to using the MOOC and to its contents?
- Are there any differences in this reaction, depending on race, gender, religion, and/or social environment?
- How does the MOOC and its contents impact knowledge gain?
- Do students feel able in transferring the acquired knowledge to practice?
- Are there differences in knowledge gain based on gender or other traits?
- Which of the contents and activities provided by this MOOC have more impact on knowledge gain and motivation?

Therefore, future work will be the analysis about how these questions are answered throughout the experiences with students.

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