Encouraging Girls in STEM: workshops on analog electronics, sensors and robotics

Claudina Rattaro, Isabel Briozzo, Mariana Siniscalchi, Florencia Blasina and Mariana del Castillo
Facultad de Ingeniería
Universidad de la República
Montevideo, Uruguay
{crattaro, ibriozzo, msiniscalchi, fblasina, mdelcastillo}@fing.edu.uy

Abstract—Female students, researchers and employees are under-represented in science, technology, engineering, and mathematics (STEM) related fields. In many countries this has resulted in projects and initiatives aimed for promoting gender equality. To overcome the leaky pipeline phenomenon, which occurs mostly in secondary school, our University has been carrying out different actions to encourage girls to enroll in STEM careers. In this article, we focus on Taller Electrizante experience which is conducted by women teachers of the Electrical Engineering Institute of the School of Engineering. It consists of two independent modules: Laser Communication and Robotics with Arduino, where several disciplines related to Electrical Engineering and Communication Systems are presented in hands-on workshops applying the role model approach.

Index Terms—women and STEM careers, role model approach, robotics, telecommunications, analog electronics.

I. INTRODUCTION

Women’s persistent under-representation in science, technology, engineering, and mathematics (STEM) education, occupations, and careers around the world have given rise to projects and initiatives aimed for promoting gender equality. Some representative examples are: Women’s Technology Program (WTP), MIT Women’s Initiative (MWI) (both performed by the Massachusetts Institute of Technology (MIT)), the “Meninas Digitais” program in Brazil, the international initiative “Girl who code movement”, etc. For more information see [2]–[8] and the references therein.

In our country, various actors of education, government, civil society, and the software industry, participate including Facultad de Ingeniería (School of Engineering) of Universidad de la República, in the annual celebration of the International Day of Girls in Information and Communication Technologies (ICT) each April. This is a worldwide initiative promoted by the ITU (International Telecommunication Union) to encourage and empower girls and young women to consider studies and careers in the growing field of ICTs. For several years, Facultad de Ingeniería has celebrated this day inviting high-school students to visit research labs at Computer Science Institute (InCo) and Electrical Engineering Institute (IIE). The activities involve from poster sessions and guided tours to hands-on workshops for groups of female high-school students. Since 2017, ninety-minute workshops were held for girls to interact with the “Butiá” robot, experiment with analog circuits, create digital maps, play with mathematics and experiment with physics. Article [8] presents the different activities carried out by teachers and researchers at the School of Engineering to promote ICT careers among high school girls in Uruguay. In the present article, we focus on the workshop coordinated by teachers of IIE, called Taller Electrizante experience.

In the workshop several disciplines related to Electrical Engineering and Communication Systems are included. The purpose is to put the focus on areas such as electronics, robotics, programming, wireless communication and signal processing (areas linked to ICTs).

The main contributions of this article are:
• sharing the technical details of the proposed workshops so that they can be reproduced by other universities/institutions,
• sharing our experience and results working in gender-STEM topics, and
• raising awareness of gender inequality in science and technology.

The rest of the article is organized as follows: in Section II we summary some aspects of the methodology, in Section III we present a set of two hands-on workshops which constitute Taller Electrizante, while Section IV discusses some preliminary results. Finally, Section V presents conclusions and future work.

II. METHODOLOGY

The activities are aimed for girls between twelve and fifteen years old, since at that stage they have not chosen the area for their undergraduate studies, yet. These areas are science and engineering, arts, biology and social sciences.

All the activities are organized by female teachers and researchers, following a role model approach, as a way to showing girls the female participation in electrical engineering and computer science. In addition, female Electrical Engineering students help out with the activity. Their participation is
voluntary but we give them some credits that they can use in their curricula.

Twenty to thirty girls participate in each shift (four shifts in total), organized in teams of three to four participants. Each team is assigned to one of the modules according to the girls’ age.

III. DESCRIPTION

The workshop consists of two independent modules: Laser Communication and Robotics with Arduino. The former introduces the participants into analog circuits and sensors, by means of an application to a simple on-off laser light communication. The latter focuses on the use of micro-controllers, programming, sensors and robotic systems. In this section, both activities are thoroughly described.

A. Laser Communication

The goal of this activity is for participants to have a first approach to and interact with analog circuits, as well as understanding how a communication works.

Figure 1 shows a diagram of the system. A distance on-off keying communication is engaged from a transmitter (Tx) to a receiver (Rx). The output of the transmitter consists of an on-off laser light. In order to command the laser light, the transmitter includes a light sensor, thus, turning on the laser when a non-coherent light reaches the light sensor. On the other hand, the receiver has its own light sensor, which is also part of the conditioning circuit of a speaker. Thus, the receiver is a light to sound transducer. In this way, the speakers audio signal can be remotely turned on and off.

![Fig. 1: Laser communication system diagram.](image)

From a constructive point of view, both circuits consist of two main modules each. The transmitter has a light detector module and voltage regulator module. The receiver has also a light detector module and a speaker module. Light Dependent Resistors (LDR) are used in both light detector modules, as seen in the schematics in Figure 2. The names, values and part number of the components are listed in Table I. The circuit topology was selected and the circuits were designed and built into PCBs, by undergraduate female students with the assistance of electronics teachers.

Each circuit kit handed to the group consists of the main board with most of the components assembled on it, as well as sockets or pins for plugging the missing components, as seen in Figure 3. All the pluggable components are handed separately. The action to be performed by the girls is to plug the components, that is, deciding where each component should be plugged by visually inspecting the circuit as if it was a puzzle. In order to accomplish that, the girls are aided with the circuit schematics as well as drawings showing the physical appearance of each electrical component in the circuit, including a brief and simple description. This let the
girls identify the components and also know their polarity. Moreover, different values of $R_2$ are available to plug and unplug in order to obtain different sound frequencies.

The groups of girls interact during the whole process with electrical engineering female teachers and students, who assist them and answer their questions.

*Fig. 3: Part of the transmitter (up) and part of the receiver (down). It is possible to see removable components.*

The workshop starts with a brief introduction on how the system works and some basic safety rules. The girls were organized in groups of three to five members. As the transmitter is somewhat more difficult to build than the receiver because of the voltage regulator, the elder girls are preferred to work with the transmitter and the younger girls with the receiver. Each group is provided with a kit (either transmitter or receiver). At the end of the workshop, each group working with the transmitter would pair up with a group working with the receiver, in order to test the communication between transmitter and receiver. This allows the girls to understand that there are several levels of verification and that the systems are built from blocks.

*Fig. 4: Laser Communication.*

In our experience, the guidance and constant assessment are essential to some teams. It depends, not only on their age, but also on their enthusiasm and ability to work as a team. It is also necessary to have spare components in case of failure or loss. Every team completes the task successfully. Figure 4 shows girls working in the Laser Communication Workshop.

**B. Robotics with Arduino.**

This activity has the purpose of introducing the participants to micro-controllers and robotic systems, as well as helping them understand what programming is. The system we work with, shown in Figure 5, is a robot consisting of a DC-engine$^3$ and two wheels connected to an Arduino UNO board$^4$. The choice of Arduino is due to its versatility, the many examples that it provides to beginners and to remark the advantages of open source hardware and software.

As in the previous workshop, the girls are organized in teams (approximately three teams of five girls) and are supervised by an instructor (a female engineer student or teacher). Each team is provided with two instructives, one with several tips for programming, and one with the proposed challenges.

First, the instructor discusses the meaning of programming with the participants, as a way of giving instructions to the micro-controller, and reviews all the tips to program a basic program in Arduino. These include:

- How to set the pins of the board:
  
  ```
  void setup() {...}
  ```

- The function that is repeated continuously:

  ```
  void loop() {...}
  ```

- Every sentence has to finish with “;”.

- How to build a function and examples.

$^3$Driver: L298D.

$^4$https://www.arduino.cc/.
• The difference between digital and analog outputs.

Once the participants have understood the tips, they proceed with their first challenge, which consists of experimenting with a simple code of Arduino, Blink. The girls have to verify the code and upload it to the board. This allows them to see what the program does and make it easier for them to understand the instructions afterwards. Then, they are asked to modify the code to change the time the led is on.

The second challenge involves controlling the robots and the level of difficulty increases significantly. First, they have to analyse a code, written by the instructors, that moves the robot in a certain way. A shortened version of this code is as follows:

```c
/*Setting Pins as outputs*/
void setup() {
  pinMode(enDerecha, OUTPUT);
  ...
}

/*What my program does*/
void loop() {
  /* Both wheels go forward */
  izqAv(150);
  derAv(150);
  /* Both wheels go backwards */
  izqRev(150);
  derRev(150);
  /*Turns to right*/
  izqAv(150);
  derStop();
}

/* Definition of the functions used*/
void izqAv(int vel) {
  analogWrite(enIzquierda, vel);
  digitalWrite(izquierdaFw, HIGH);
  digitalWrite(izquierdaRv, LOW);
}

5
```

The comments on the code were translated for better understanding.

The program presents many of the characteristics introduced to the participants at the beginning of the workshop. They have examples of how to set pins, what sentences have to be in the function `loop()`, how a function is built, and why it is useful to have two different kinds of outputs, digital and analog. For instance, the function `izqAv()` uses both kinds, one analog output to indicate the velocity, and two digital ones to indicate the turning direction, forward or reverse. Taking all this into account, the participants have to deduce, with no comments on the code, how the robot is going to behave.

In the following task, the girls have to modify the base code so that the robot can move in a different way. This include changing the time the robot moves forward or backwards, changing the velocity to make it faster or slower, and adding a reverse sign. For this task, the girls have to think about how they could incorporate the `Blink` code into the present one.

Finally, the girls can also experiment with robots that have light and ultrasound sensors.

The participants face challenging electrical engineering problems. Even though it is their first experience with circuits and programming, the girls are engaged in the activity and achieve the tasks successfully.

It is important to highlight that many of the participants do not have much of an idea of what an electrical engineer is. Therefore, the workshop helps to open new possibilities of professions that they were not taking into consideration.

The great enthusiasm showed by the attending girls proves that the motto “learning by doing” has positive effects when encouraging youngsters pursuing a career in engineering.

This workshop has been carried out for three years, 2017, 2018 and 2019, and we have received 70 participants each year, in average. Every year, all participants and teachers in charge are asked to fill a survey regarding their opinion on the
activity. Some personal questions are also included to gather valuable information to make a thorough analysis of what barriers girls have for studying engineering. The results of these surveys are presented in [8]. According to the results, we may conclude that the event met the expectations of most participants (see for example Figure 7).

![Fig. 7: Institution feedback about the workshop (with 5 being excellent).](image)

V. CONCLUSIONS

We believe that this type of activities with high school girls are key to promote STEM careers among young females, while contributing to the elimination of stereotypes and making the participation and contributions of women to the area more visible.

We are also aware that this isolated efforts hardly make any difference on their own, but they do together with other efforts that are being carried out in our country and all over the world.

In 2018 we submitted the complete project proposal to the FRIDA Awards, Technology and Gender category⁶, which were launched that year. In that edition, our project was awarded with one of the prizes⁷ ⁸. The FRIDA prize will let us continue with these activities as well as to carry out a pilot edition of a new project.

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REFERENCES


⁶https://programafrida.net/en/awards
⁷https://programafrida.net/en/selected-projects-2018