A ROBOTIC HAND STARTER KIT WORKSHOP IN PARTNERSHIP WITH A PUBLIC SCHOOL

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Abstract. The absence of women in hard sciences in Brazil is a reality. The scenario is similar at the Instituto Tecnológico de Aeronáutica (ITA), one of the most renomade institutions of higher education in Brazil. The bioengineering group was one of the initiatives inside the STEM2D project. This paper presents a part of our work, the development of a complete project for high school students. Mainly, the project aimed to encourage and engage girls in STEM careers by building multidisciplinary skills and bioengineering knowledge in high school. In four sessions, undergraduate and graduate students from ITA and public school teachers conducted the activities to assemble the robotic hand with the students. The chosen activity was a robotic hand, initially proposed by Microsoft, with some modifications in order to reduce costs and also enable the assembling in a short time. The developed resources were made publicly available for reapplication. Through this material we expect to contribute to science dissemination and a major student's engagement in STEM careers especially the female students.

Key-words. Bioengineering, Women in STEM, Public Schools

1. INTRODUCTION

The presence, or more often the absence, of women in STEM (Science, Technology, Engineering, and Mathematics) fields is a dynamic and multifaceted phenomenon in which there is no full agreement on the causes, much less on the solutions. Despite the possible divergences, in Brazil at least, this phenomenon is a reality. According to the Higher Education Census of 2020 [1], among the twenty major careers, in number of enrollments, there are three belonging to STEM careers and they possess the minor presence of women: Production Engineering, 32.7%; Civil Engineering, 29.9% and Information Systems with only 15.3%. This is an example among

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many of women's statistics in Brazil.

Some data from international tests point to differences in the school performance of boys and girls. For example, in the Regional Comparative and Explanatory Study of 2013 [2] an international assessment directed at the countries of Latin America and the Caribbean, students in the 3rd year have a mathematical performance superior to that of boys in more than 10 points. In the 6th year, the picture is reversed, with boys averaging 10 more points in performance. The secondary education data from Pisa of 2015 shows that boys outnumber girls in science and also in mathematics, where the difference is more than 10 points [3]. For some reason, during the first cycle of elementary school there is a change in the scenario that continues until the high school years. Perhaps because during these years children seek references for choosing their careers and it could be difficult for girls to find references in science.

The statistics in other hard sciences such as biology, astronomy and physics also express low female presence. Morcelle and colleagues [4] carried out a research on gender and ethnicity in the CNPq (National Council for Scientific and Technological Development) database. The data show a decrease in the presence of women, especially black women, according to career progress. The authors also developed a survey with high school students and observed that almost 80% of students associated scientists with white men. The identification of women with scientific careers was less than 2% and no black woman was associated with science. It can be observed that it is difficult for girls to find references inside this scenario.

The lack of representativity seems to influence women choices not only in the elementary and high school but also in the university. Among women who enrolled in careers in the exact sciences the dropout rate is higher when compared to that of men. In a university where, after completing a basic cycle of courses, students can choose some career options, Sass and colleagues [5] conducted a survey relating the students' performance in the introductory technology courses and their interest in the areas of computing. While in the introductory technology courses the presence of women was 30%, the percentage of female students enrolled in the Bachelor of Computer Science (BCC), dropped to 18.9%. The results of the last five years showed that women and men performed similarly in introductory technology courses and their performance does not explain the decrease in the presence of women.

Moreira and colleagues [6] also noticed a decrease in the presence of women inside the courses of exact sciences. They report data from a university in the southeastern region of Brazil, in the BCC the presence of women is 10.2% of students enrolled; in Computer Engineering (EC) they represent 13.8% and in Computational Mathematics (MC) they are 21%. Based on historical quantitative data, the research presents trend curves for future scenarios regarding the perspective of the presence of women in STEM areas. Based on the rates of reduction of the presence of women in the three courses above mentioned, the authors present forecasts that, without interventions to reverse this situation, there will be no more women in 2050 at the BCC, in EC there will no longer be a female presence in the year 2031, while in MC there is a trend of stability.

2. PROBLEM AND OBJECTIVES

The scenario is similar at the Instituto Tecnológico de Aeronáutica (ITA), one of

the most renomade institutions of higher education in Brazil, located at the city of São José dos Campos. Despite the institution having started in 1950, it only accepted women from the year of 1996. Until now the women represent less than 10% of the enrollments [7]. The institution was the only in Latin America to participate in the Science, Technology, Engineering, Math and Manufacturing (STEM2D) Project, conceived by Johnson&Johnson in 2016. The project aims to increase female participation in the science and technology area and encourage women to enroll in the following courses: Science, Technology, Engineering, Mathematics, Manufacturing and Design. The initiative ís carried out by professors and students from ITA, mainly women.

The bioengineering group was one of the initiatives inside the STEM2D project. We developed our activities during the academic year of 2021. This paper presents a part of our work, the development of a complete project for high school students. Mainly, the project aimed to encourage and engage girls in STEM2D careers by building bioengineering skills and knowledge in high school. In addition, the project development intention was to promote hands-on experience and show that everyone can do science and follow a career in this field. Bioengineering is a multidisciplinary area, with interfaces from basic science to applications in medicine, which includes engineering, chemistry, and mathematics knowledge to offer new solutions.

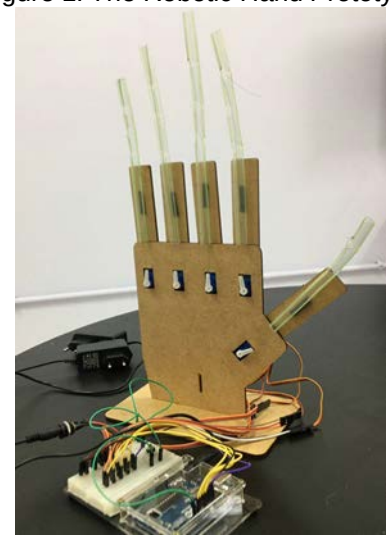
With this project we have:

- **Developed** a workshop involving concepts of biology and technology;
- **Made publicly available** the instructions of the workshop, in a way that teachers and educators could replicate it;
- **Started** a partnership with a public school, offering (low income) students the opportunity to participate in the project;
- **Engaged** students in the STEM areas through a hand-on activity;
- **Applied** the workshop by a team of women, giving references to the female students and also contributing in the training of graduate and under-graduating students.

3. ACTIVITIES DEVELOPED

The bioengineering group was composed of: two professors of ITA, two graduate and one undergraduate student of ITA and two Math teachers of state public school. During the pandemic, the classes at ITA were for the most part virtual, due to the sanitary restrictions. In this way our group was divided in different cities and our meetings took place virtually. Once a week we discuss the developed actions and the next steps of our project. To decide what activity we would develop with the students, all members presented possibilities and we decided for the development of a robotic hand through targeted activities. This project was inspired by the Hacking STEM Microsoft program 1. Through the teachers of our group we established a partnership with the high school Ayr Picanço.

Figure 1: The Robotic Hand Prototype



Source: Authors

Another difficulty from the pandemic was the material preparation, since we could not meet to test materials and assembling, sharing knowledge and experiences. In this way we found some difficulties in implementing the original Microsoft proposal since not all group members would have the necessary knowledge. Besides that, the cost of the original proposal was over budget and the time to develop the project with the students would be limited. So we decided to adapt the project to our context and propose the Robotic Hand Starter Kit with some modifications compared to Microsoft's program kit. Instead of using a glove sensor, push buttons were used for performing the hand's finger movements. Our intention when designing the activity was to assemble a material that could be employed several times, being reused by other groups. In this way MDF pieces were employed for the hand's assembly, figure 1 shows our prototype. However, in a cheaper (and less durable) version, the material used could be cardboard. The decisions about the project modification were taken in our weekly meetings. Hence, the kit assembled contains servo motors, MDF pieces, plastic straws, nylon line, pushbuttons, glue, scissors, 220 Ohm resistances, and tape. With this adaptation we reduced the cost to run the workshop, also facilitating its reproduction in other scenarios. Table 1 presents all components of the kit and their quantities.

Table 1 – Items and quantities that compose the kit.

Components	Quantities
Scissor	1
Double Sided Tape	1
Straw	5
Nylon line	1
MDF pieces	1
Servo Motor	5
Jumpers	20
Push Button	1
Breadboard	1
Arduino board	1
USB cable (A to B)	1
5V power supply with breadboard connection	1

Each member received a kit and we tested the project separately discussing the difficulties in our meetings. Another problem was deciding the format of the workshop since there was not a clear decision of the government about the reopening of schools. With the teachers of the school we decided on a face-to-face format, appling the workshop as soon as possible when the students returned to the school. The available time to develop the workshop would be four sessions of one hour and thirty minutes. Our intention was connect theory and practice, in this way we divided the content in the following steps:

First class: A brief explanation of the workshop, speaking about the STEM²D project, the people involved and the objectives of developing the robotic hand. Besides that the class should present the bioengineering connecting life sciences and technology, showing the relation between the hand anatomy and prosthesis uses. As the hands-on activity the students were instructed to produce straw fingers. Also we have created awareness of the low presence of women in STEM.

Second class: In this class the students resumed building the hand by working with a MDF base to attach the straw fingers. After that they will receive an introduction to electronics, Arduino and its programming language. The students then learned how to assemble the electronic components and manipulate the Arduino code to move one finger.

Third class: This class starts with a discussion about how the Arduino code works to move one finger. The students should propose modifications to insert another finger in the project. After discussion they will be instructed to replicate the steps of moving one finger to generate the complete hand movement. For this, they should prepare the complete electronic circuit and manipulate the Arduino code.

Fourth class: In the last meeting, a push button will be inserted in the circuit to activate the hand movements. They students will also learn a bit more about the Arduino code and were challenged to manipulate the code creating different hand movements.

To prepare the class's contents we had the support of the teachers in our group, since they know the students and their context. With the workshop schedule approved by the teachers, the team also wrote scripts, prepared slide presentations and forms for this project application and the necessary material for the workshop reproduction. The material is available in portuguese. When the students returned to the school we applied the workshop. During four weeks, between October and November of 2021, one or two members of our group went to the school to meet the students.

4. ANALYSIS AND DISCUSSION

In four sessions, undergraduate and graduate students from ITA and public school teachers conducted the activities to assemble the robotic hand with the students. The participants learned about anatomy, biomechanics, Arduino programming, and robotics. This activity integrated life sciences with robotics while incorporating 21st-century technical skills like data science, software, mechanical and electrical engineering for an authentic learning experience. Emphasis is placed on the importance of combining science and technology to reflect the mechanics of the human body. Through the activity, the students learned to articulate the movement of human fingers – made with plastic straws – by assembling an MDF hand and connecting several sensors to visualize how bones work

within the skeletal system. Using an Arduino microcontroller, the sensors are activated to perform various movements through the controllers.

During the classes we offered some theoretical concepts and developed a part of the project. The workshop was offered inside the Math classes and students were able to choose whether they wanted to participate, or not. We used the digital resource room, a room with computers and enough space to receive 20 students, maintaining the number of people per square meter indicated by candle surveillance measures to contain COVID-19. Students and teachers wore masks during the activities. The students were grouped in pairs to execute the hand-on activities, this choice was made thinking in the distance measures, in other contexts of the disease we believe that the groups could be of three or four students, allowing to apply the workshop to a greater number of students. Figure 2 shows the workshop application.

Figure 2: Students working on the Robotic Hand Starter Kit.

Source: Authors.

Concerning the workshop application, we were not able to complete all the planned steps. In the first and second meetings the time was adequate for the development of the proposed activities. In the third class the complete assembly of the hand and the electronic circuit took more time than was fixed and this step extended to the fourth class. In this way we did not reach the content of the fourth meeting. For this reason we think that the material could be adapted for five weeks, or more, since, as it happens in all learning activities, the planning evolution depends on the context of the target group. In this way, the material made available can be edited and adapted. Besides that, the presence of the facilitators (teachers, educators, monitors) that have previously assembled and tested the project is extremely important to guide the students through the possible mistakes while connecting the electronic components and manipulating the Arduino code. In our case we intend to train more students of the STEM²D project to act as monitors in future applications of the workshop.

We reached our objectives of developing a partnership with a public school to foster STEM activities, we have developed, applied, and made public the material of the workshop. Besides that we conducted the complete workshop headed by a female team, offering to the high school students references in the STEM careers and also giving an important experience for the graduate and undergraduate students that carried out the

workshop. As a limitation of this work we point out that the absence of an impact evaluation in the students' engagement. We received positive feedback from the teachers and students, but we did not measure the project impact.

5. CONCLUSIONS

In this work we presented a workshop development and application in partnership with a public school. The chosen activity was a robotic hand, initially proposed by Microsoft. Considering the challenges of building the robotic hand, we introduced some modifications in order to reduce costs and also enable the assembling in a short time, optimizing the impact of the initiative. The activity was developed through four meetings, when the students learned about some theoretical concepts and also developed hands-on activities. Furthermore, the class's content was focused on this topic's interdisciplinarity. A group composed of professors, students and teachers developed the necessary material and led the workshop. The developed resources were made publicly available for reapplication. Through this material we expect to contribute to science dissemination and a major student's engagement in STEM careers especially the female students.

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