Analyzing The Impact Of Hands-On Activities In A Public School

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Resumo: *The scarcity of professionals in STEM careers is a significant concern, and studies have shown that students' lack of motivation plays a role in their decision to avoid pursuing careers in the hard sciences. To address this issue, several initiatives have been implemented to present STEM careers in a more engaging and attractive manner. One such initiative is the STEM2D project at XX University, which offers various activities to support undergraduate students and encourage girls to pursue careers in STEM fields. In 2021, the project included the development of a bioengineering course for high school students. In this study, we examined the impact of this course on students' perceptions of STEM. Our findings shed light on the following key observations: the activity had a positive impact,* *increasing students' interest in STEM areas although it did not move them to plan achieving a career in hard sciences. Activities with sustained and continuous impact are more may be needed to influence career decisions.*

Palavras-chave: *Women in STEM, Hands-on activities, Teenager motivation in STEM, Public schools*

Analyzing the Impact of Hands-on Activities in a Public School

1 INTRODUCTION

The scarcity of professionals in Science, Technology, Engineering and Math (STEM) careers is a prevalent concern, both globally (Hossain and Robinson, 2012; Wang and Degol, 2013; Bahar and Adiguzel, 2016) and specifically in Brazil (Tozzi and Tozzi, 2011). Numerous studies exploring the factors influencing students' career choices have highlighted the lack of motivation as a significant reason for avoiding careers in STEM (Hossain and Robinson, 2012; Wang and Degol, 2013; Bahar and Adiguzel, 2016; Degenhard et al., 2007). Consequently, initiatives aimed at presenting STEM careers in a more appealing manner have proven to be effective in cultivating students' interest, ultimately influencing their inclination towards studying STEM disciplines (Aeschlimann et al., 2016; Hiğde and Aktamış, 2022).

There is also a gender gap in career choice and other issues prevent girls from optioning for a STEM profession. They also face a lack of representativity and stereotypes that associate the hard sciences with male professions (Wang and Degol, 2013). For this reason, several initiatives have been focusing on this public (Prieto-Rodriguez et al, 2020). The STEM^{2}D project, situated at the *Instituto Tecnológico de Aeronáutica* (ITA), is one such initiative that coordinates various activities aimed at supporting undergraduate students in their career pursuits and encouraging girls to follow careers in hard sciences.

In 2021, one of the branches of the STEM^{2}D project was the development of a bioengineering course for high school students. The primary objective of this project was to encourage young people to consider pathways in the hard sciences by providing an engaging learning experience that integrated theory and practical activities. To achieve this, a new hands-on workshop was formulated, emphasizing the correlation between biology and engineering. One professor led the initiative, alongside the participation of two graduate students, one undergraduate student, and two Math teachers from the state public system.

During the academic year, the workshop was prepared remotely due to the ongoing COVID-19 pandemic and happened in person when in person classes resumed. Our group adapted a robotic hand starter kit, which was a streamlined version of the Hacking STEM Microsoft program's original robotic hand project[1]. The original project consisted of two modules: a glove embedded with sensors and a hand prototype. By wearing the glove, finger movements were detected and translated by an Arduino board to control the gestures of the robotic hand. In our version, we focused solely on the robotic hand module and modified the approach by utilizing coding to control the fingers' motion.

The workshop was divided into four modules, each comprising a concise explanation of the underlying concepts related to the project, followed by hands-on

[1]https://learn.microsoft.com/en-us/training/educator-center/instructor-materials/build-machines-that-emulate-humans

activities. On the final day of the workshop, students were requested to complete an online form, which included four open-ended questions and one scale question, with 12 sentences, to gauge their overall experience. Additionally, the Math teachers who participated in the workshop provided written feedback about the course, sharing their perspectives and insights.

In a previous study (Valeriano, 2022), we provided comprehensive details regarding the activity development, the decision-making process, and the challenges encountered in organizing a hands-on workshop within the context of the pandemic. Additionally, the materials created for the course were shared in a public repository, enabling its replication[2]. In this study, we shifted our focus towards analyzing the impact of the course on students' perceptions of STEM and STEM careers. To assess the effectiveness of the workshop, we analyzed the responses provided by the students, comparing the scores assigned to various statements, and also considered the feedback and observations of the teachers involved.

2 ACTIVITIES DEVELOPED

2.1 The workshop

The workshop was conducted between October and November of 2021 at a public school, utilizing the multimedia room equipped with computers. The course was integrated into the regular Math classes and was offered to first-year high school students as an optional activity. Among the participants, a group of 20 students, 10 were girls. The sessions took place once a week, with each session lasting approximately one hour and thirty minutes. Each session was led by one or two members from the STEM^{2}D project, who guided the students through various concepts encompassing electronics, mechanics, coding, anatomy, and bioengineering.

Figure 1 depicts the prototype of the robotic hand assembled in the workshop. The base and hand were constructed using MDF (medium-density fiberboard), while the fingers were fashioned from plastic straws. The hand was attached to the base, and the fingers were fixed in place using double-sided tape. To simulate human-hand movement, the servo motors were affixed to the hand and connected to the fingers through nylon wires. As the servo motors rotated, the straws bent, replicating the desired movements. The servo motors were connected to a breadboard and powered by a 5V power supply. Next, we provide a detailed account of the workshop's contents and activities conducted during each session.

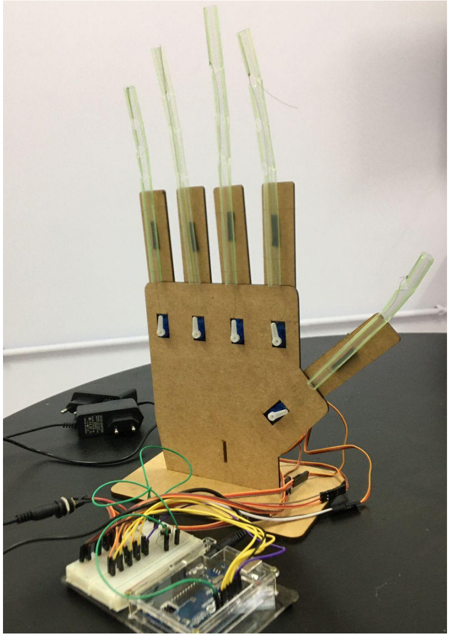
Week 1: In our initial session, our primary objective was to familiarize the students with the project. We also gave a brief introduction about the STEM^{2}D project and raised awareness about the existing gender gap in STEM careers. We offered a theoretical class on hands anatomy, mobility, prosthesis use, and bioengineering. Finally the students constructed the straw fingers. By pulling the nylon strings, the students were able to simulate the human-hand movements.

Week 2: Our second week began with the completion of the assembly of the robotic hand, where we glued the straw fingers and attached the hand to the base. After, we provided a concise introduction to electronics, illustrating the significance of circuits in our

[2] https://github.com/gabivaleriano/RoboticHand

daily lives through basic examples. Additionally, we introduced the Arduino and how it can be programmed. To engage the students further, we shared code to move one single servo motor. The class concluded with the practical execution of the code, enabling students to see the servo motor in action by moving one finger of the robotic-hand.

Figure 1: The Robotic Hand Prototype.



Source: authors

Week 3: Our focus on the third week revolved around understanding the code responsible for controlling the servo motor. We thoroughly explained the code and encouraged the students to actively participate by challenging them to modify it and create different patterns of movement. Moreover, we introduced the students to the complete circuit necessary to control all the fingers of the robotic-hand. Emphasizing the importance of attention to detail, we provided instructions for placing all the components in their correct positions. The students were supposed to also use the code and execute the complete hand movement on this day, but we did not have enough time to complete the schedule.

Week 4: Originally, the plan for this week involved the students incorporating a push button into the circuit to activate hand movements. Following that, we intended to challenge them to create various hand gestures by manipulating the code. However, we were delayed since we did not manage to finish the activities proposed on the third day. Besides that, we experienced issues with some malfunctioning jumpers, which resulted in a significant amount of time being spent on identifying and isolating the problematic components within each kit. Consequently, we found ourselves with insufficient time to complete all the intended activities. While none of the groups were able to fully accomplish the project by achieving movement in all the fingers, it is important to note that every group was able to successfully move some of the fingers in the robotic-hand.

2.2 Accessing students perception

After the completion of the workshop, students were given the opportunity to answer the following questions freely, without any stipulation of text length:

Question 1: What did you like the most about this project?

Question 2: What did you like the least about the project?

Question 3: What did you learn during the course?

Question 4: How can the course be improved? Please provide your suggestions.

Additionally, students were presented with a set of twelve statements to be rated on a scale from 1 to 5, with 1 indicating '*Disagree*' and 5 indicating '*Agree*'. The statements are as follows:

Question Set 5: (Set of Likert scale questions). During this course...

1. I used my creativity.
2. I worked together with my classmates.
3. I exercised leadership.
4. I learned about prostheses and robotics.
5. I felt able to develop the hands-on project.
6. I achieved the objectives proposed in each activity.
7. I felt able to modify the project.
8. I had all the necessary materials to develop the project.
9. I learned in class all the necessary concepts to develop the project.
10. I felt challenged to complete the activities.
11. My interest in STEM increased.
12. I am thinking about following a career in STEM.

Furthermore, the two math teachers who were involved in the project also provided their perceptions of the activity.

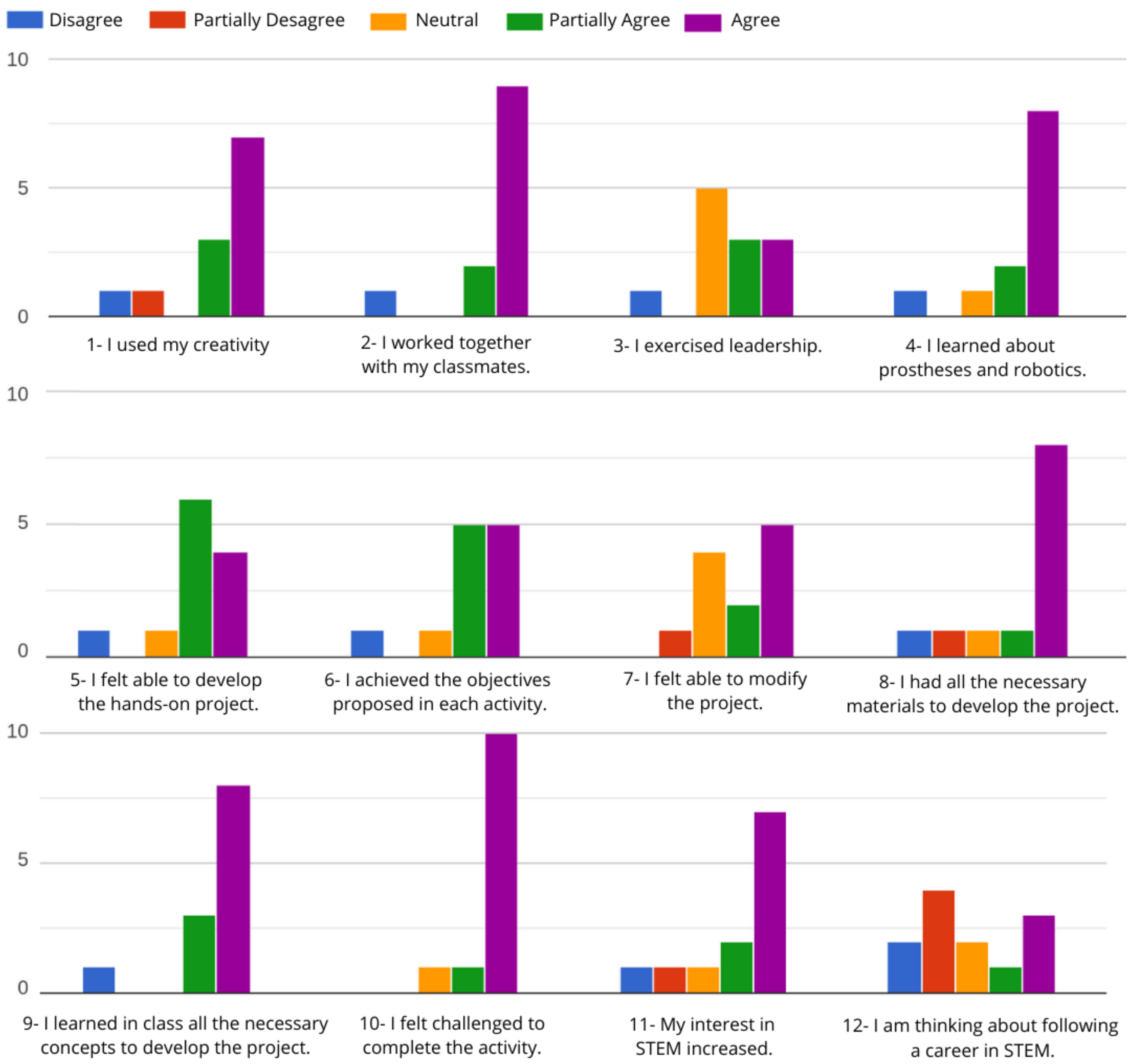
3 Results

Despite the workshop being conducted with a total of 20 students, we received responses from only 12 participants. The answers provided were generally brief, with an average length of 10.9 words. Below, we provide a summary of the responses for each question. Additionally, Figure 2 presents the scores assigned by the students for the statements.

Question 1: Out of the respondents, five students expressed their enjoyment in engaging with the project, using phrases such as "*working with technology*" and "*realizing the practical application of materials*". Three students specifically mentioned their appreciation for learning about Arduino and electronics. Furthermore, five students highlighted their satisfaction with gaining knowledge in coding. According to the teachers' perceptions, the students' most memorable moments were witnessing how the rotation of the servo-motor translated into finger movement.

Question 2: Four students mentioned issues with assembling the electronic circuit and expressed disappointment in not being able to complete the project and seeing its full functionality. The teachers acknowledged this as the only negative aspect, as it led to some frustration within the group. Three students encountered difficulties in assembling the hand and working with the nylon string for the fingers. Two students expressed a desire to learn more about coding and write their own code from scratch, without relying on pre-existing code to modify. One student suggested that the duration of the course should be extended, as it was too short to cover all the desired content.

Figure 2: Graphic representation of students' answers for the proposed 12 statements.



Source: Authors

In response to **Question 3**, Five students specifically mentioned learning about Arduino and its functionality. They highlighted understanding how an Arduino works. Additionally, five students emphasized the significance of coding and its practical application. They used phrases such as "*learning how to apply coding in a tangible project*" and "*gaining knowledge in coding for a robotic hand*". Three students mentioned the robotic-hand assembling. Furthermore, three students noted the development of soft skills such as teamwork, communication with peers, and creativity. There were two references to learning about the functionality and importance of prostheses, and one reference to understanding the mechanics of the human hand. Both teachers also commented on the improvement they observed in students' ability to work effectively in groups.

Regarding **Question 4**, four students mentioned issues related to the materials used, including problems with the jumpers and the time-consuming process of using double-sided tape to fix the hand components made of MDF. One student expressed the desire for more instructions and guidance during the workshop sessions. Three students and the teachers suggested that the duration of the course could be extended to allow for more comprehensive learning. Additionally, two students indicated that the course could have placed more emphasis on coding. The teachers provided two suggestions for improving the workshop. Firstly, they recommended providing a printed step-by-step guide for the students, in addition to the digital instructions already shared. The printed version would be more easily manipulated and accessible. Secondly, they proposed pre-assembling the base of the hand, which would give students more time to focus on coding and other aspects of the project.

4 Discussion

This project aimed at cultivating students' interest in STEM fields and motivating them as one way to increase the likelihood of them choosing STEM careers. The activity was conducted within the new model of high school education in Brazil (Novo Ensino Médio), which began in that same year. Under this new model, students are required to choose a specific educational pathway by the end of their first high school year, leading them to study related subjects. The fact that students from various pathways chose to participate in the workshop indicates that hands-on activities have the potential to spark students' interest across different areas of study.

Based on the feedback received from students, it is evident that the workshop had a positive impact. This can be seen in their responses to Question 1 and Statement 11, where students expressed their enjoyment and interest. Students also felt that they learned theoretical concepts, as indicated by Statement 4. They felt challenged by the activity, as reflected in their agreement with Statement 10. However, it is worth noting that despite these positive outcomes, the workshop did not directly influence students' career decisions, as indicated by Statement 12. This may be in part, to our inability to complete the project, which resulted in some frustration, as reported by the teachers and by some students in question 4. It is important to recognize that activities with a sustained and continuous impact are more likely to influence students' career decisions (Prieto-Rodriguez et al, 2020). Therefore, this workshop can be seen as a first step, and further engagement and follow-up with the students would be necessary to have a lasting impact on their career choices.

One teacher suggested employing less time in assembling the prototype and more time focusing on coding. Regarding this point, and also the suggestion (Question 4) of extending the course, we believe that the activity can be adapted to different contexts and objectives based on the available time and the goals of the group. For example, providing pre-assembled hands and focusing solely on coding can be an option, depending on the educator's objectives. In our case, we aimed to involve as many areas as possible in the course to generate students' interest, recognizing that different steps in the activities can elicit different levels of engagement. The students worked in pairs, due to the pandemic restriction measures. In a different scenario, with the possibility of working in small groups, each student could carry out a step of the project (mechanical assembling, electronic circuitry, coding), working as part of an engineering team.

We agree that a printed manual would be beneficial, and in future versions of the course we plan to produce and distribute it to the students. Another noteworthy aspect is the varied perception of coding among students. Some students appreciated learning about coding, as indicated in their responses to Question 1, while others expressed a desire for more in Question 2, reflecting their different backgrounds and expectations.

Finally it is worth mentioning that both students and teachers believe that they improved their ability of teamwork, as evident in Statement 2 and Question 3, even though it was not initially the primary focus of the workshop. However, students did not strongly agree that they exercised leadership (Statement 3). Possibly due to the fact that they worked in pairs, emphasizing the collaborative nature of the activity. A limitation of our approach is that we did not collect responses before the workshop, making it not possible to compare the pre- and post-workshop perceptions.

5 Conclusion

This project aimed to stimulate students' interest in STEM fields and encourage their pursuit of STEM careers. The workshop successfully engaged students indicating the potential of hands-on activities to inspire interest. Feedback from students demonstrated a positive impact in terms of enjoyment, learning, and feeling challenged by the workshop. Adjustments, such as optimizing time allocation and providing a printed manual, can enhance future iterations of the workshop. The varied perceptions of coding among students and the observed improvement in teamwork skills were notable outcomes. Collecting pre- and post-workshop data would have provided further insights for comparison. It is important to acknowledge that the workshop alone did not directly influence students' career decisions, highlighting the need for sustained and continuous engagement to have a lasting effect.

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Keywords: *Women in STEM, Hands-on activities, Teenager motivation in STEM, Public schools*