A STEM Virtual Lab to Improve Girls' Attitude Towards Technology

Katherine Vergara[a]
Pontifícia Universidad Católica de Chile, Chile

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Abstract: The persistent gender gap in technology has prompted initiatives to attract girls to this area. While virtual labs are useful tools for facilitating STEM education, most approaches focus on specific STEM areas, such as chemistry or physics. This study proposes an integrated STEM approach to improve girls' attitudes towards technology careers. The study involved the development and testing of a STEM virtual laboratory that allowed girls to experiment with technology components, apply engineering concepts, and use math to solve science-based exercises in one place. Pre- and post-intervention questionnaires were used to assess attitudes towards different STEM areas. The results indicated that girls had a more positive attitude towards science compared to other STEM areas before the intervention. However, after the intervention, the girls in the intervention group had a significantly better attitude towards technology than the control group, and were also more inclined towards a technology career. These findings suggest that an integrated STEM approach could be beneficial for improving girls' attitudes towards technology, while also improving perceptions towards other STEM topics. Although the study's sample size was small, the findings provide preliminary evidence of the potential benefits of an integrated STEM approach for improving gender diversity in technology.

1 INTRODUCTION

The underrepresentation of women in technology fields has led to a widening gender gap. Notably, the percentage of women pursuing technology studies in the United States has declined from 37% in the 1980s to 20% in 2020 (Lynkova, 2021). Similarly, in Chile, women constitute only 20% of those pursuing technology careers 2020 (CTCI, 2020). This underrepresentation is problematic, not only due to the lack of diversity that stunts creativity (Franklin, 2013), but also because of the missed opportunity for economic development for women and their respective countries (Berlien et al., 2016; Fernández et al., 2021).

In response to the widening gender gap in technology, a number of initiatives have emerged in Chile's non-formal education sector aimed at encouraging school-aged girls to pursue careers in this field (BHP Foundation, 2021; UNESCO, 2021). These initiatives are geared towards the development of technical skills, such as programming, circuits or robotics as a means of promoting gender diversity in the technology sector, i.e. Laboratoria, Niñas Pro, Kodea, Technovation, Educar Chile, among others.

However, in computer science education, may be a predominant emphasis on technical, conceptual, and epistemological knowledge, with an underlying assumption that this knowledge is neutral in nature (Patitsas, 2013). Nonetheless, the meaningfulness of such knowledge is contingent upon its adaptation to the characteristics of the learners and their approaches to learning (Herrenkohl et al., 2019).

An approach to adapt computer science learning to girls is integrating their technical learning with more accessible subjects (Jain et al., 2022). This study presents a virtual laboratory that aims to reduce the gender gap by using science as a hook to attract girls in middle school toward technology, math, and engineering, based in previous research about virtual laboratories and girls (Braswell et al., 2021). The aim of the study is to understand whether there will be an enhancement in girls' attitudes toward technology, engineering, and math if we include a science-based approach.

This study proposes three hypotheses:

(1) Girls will have a better attitude toward science than engineering, math, and technology in the pre-survey.

(2) In the post-survey, an enhancement in attitude towards technology, engineering, and math will be

[a] https://orcid.org/0000-0002-0751-9492

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seen in the group that uses the virtual laboratory.

(3) Girls will be more willing to choose a career in STEM post-intervention.

2 RELATED WORK

Numerous initiatives are in place to increase the number of girls pursuing careers in computer science. However, numbers remains low as technical skills are not always appalling for girls. Girls are subject to a ”collective programming” (Hofstede, 2011), which comprises psychosocially constructed and learned beliefs. Through interactions with others, biases, stereotypes, and negative affective responses towards computer science are internalized, which in turn generates a negative affective state towards technology and related careers for many girls (Charters et al., 2014).

These gender stereotypes typically become established between the ages of 7 and 11 (Banse et al., 2010). The optimal time for positive intervention may be around 12-13 years old; at this age, stereotypes can still be challenged (Robnett and Leaper, 2013), while opportunities to do so decrease from 14 years old onwards (Khan and Rodrigues, 2016). As individuals age, the regulation of gender bias becomes more difficult, even when they are aware of the stereotype (Radvansky et al., 2010).

One approach to changing the attitudes of girls towards computer science may involve incorporating more engaging subject matter, as there is evidence to suggest that combining different areas of STEM for educational purposes can be advantageous (Strobel, 2011; Flynn, 2011), e.g. combining math and science has positive effects ((Kurt and Pehlivan, 2013; Hurley, 2001; Pang and Good, 2010). In this scenario, there is an opportunity to study how science can enhance the learning of the other three areas of STEM, as there is evidence that girls feel closer to science. For instance, Chile has no difference in standard science tests among girls and boys (ACE, 2019). This situation can be encounter in most countries (Stoet and Geary, 2018).

However, the incorporation of science experiments in education can be costly due to the nature of science education being highly reliant on experimentation. Hands-on activities are expensive, which has given rise to the development of virtual laboratories (Steidley and Bachnak, 2005).

A virtual lab is a type of online platform that allows students to simulate laboratory experiments and conduct scientific investigations in a virtual environment (Kfir, 2001). It typically consists of a suite of computer-based tools and resources that enable learners to explore scientific concepts, carry out experiments, and analyze data in real-time. Virtual laboratories also reduce hazard risks, allow autonomous experimentation, and are an option for students in rural areas (Aljuhani et al., 2018). Additionally, virtual education were critical for STEM education during the pandemic (Radhamani et al., 2021)

Virtual laboratories have been used for engineering (Perales et al., 2019), electronics (Evstatiev et al., 2019), and mechatronics (Vitliemov et al., 2020). Also other organizations have a wide range of laboratories, e.g. PhET interactive simulations, Labster o Laband in Physics, Chemistry, Math, Earth Science, and Biology.

However, all of these virtual laboratories focus on only one subject at a time, while this project combines the four STEM areas into one single laboratory.

3 METHODOLOGY

3.1 STEM Virtual Laboratory

In 2021, the Chilean Foundation Ingeniosas developed the STEM virtual laboratory, which was created with three crucial principles in mind:

(1) It was designed to comply with the laws of physics and nature.

(2) It was created with an intuitive interface that is accessible to students with varying levels of digital skills.

(3) It allows students to combine science, technology, engineering, and math in a single experiment.

This Spanish-language, open-access tool offers a blank workspace and a palette of elements on the left-hand side, accompanied by step-by-step instructional videos, providing a user-friendly interface. The STEM virtual lab was designed similarly to other virtual laboratories that were analyzed during the preliminary design phase.

The STEM virtual laboratory is a comprehensive tool that offers a wide range of components, including resistors, batteries, LEDs, and materials like water, vinegar, and ice. This feature allows students to experiment with technology and apply mathematical and engineering concepts to solve science-based problems. In addition, students can create prototypes using a protoboard or a white canvas within the virtual space and connect them with jumpers, allowing for a hands-on experience in a simulated environment (Figure 1).

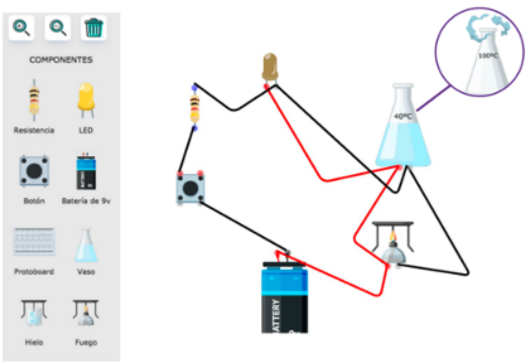

Figure 1: The lab's interface with a zoom to show the boiling water.

Also, the student can change the orientation of the pieces or change the colors of the LED and the jumpers, zoom in and out and erase and save the work in progress, as in other virtual labs.

The STEM lab provides students with the opportunity to learn and explore scientific concepts and principles in a virtual environment. Through the platform, teachers can access instructions and class plans, which outline specific experiments and exercises to conduct in the classroom. These include astronomy and earth sciences problems that require the use of engineering, math, and technology to be solved.

In addition to following the teachers instructions, students can also engage in self-guided experimentation by accessing videos that offer exercises to guide their experimentation. This allows them to work autonomously and at their own pace, while still receiving the support and guidance needed to conduct experiments successfully.

Furthermore, the STEM lab also allow for student-led experimentation, giving them the freedom to propose their own experiments and problems to solve. This provides a unique opportunity for students to develop critical thinking skills and to explore their own interests within the field of STEM. (Figure 2).

3.2 Experimental Setup

This study used a STEM attitude scale designed for school-age children, evaluating attitude and effect on a future career choice at a particular moment (Benek and Akcay, 2019). Assistance to the intervention was not mandatory by the school. The participants were students at an all-girls middle school in a low-income context in Chile. A class of 38 students was invited and subsequently divided into two random groups: a control and an intervention group.

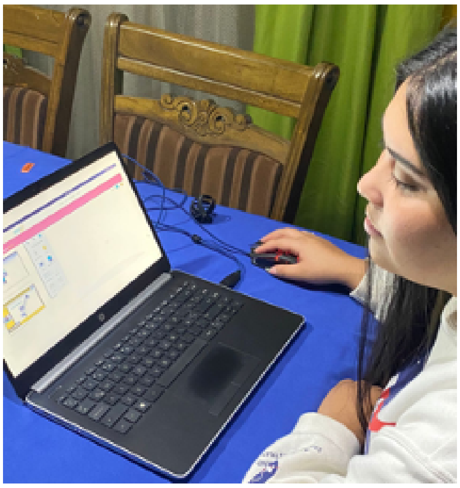

Figure 2: STEM virtual laboratory in use.

Table 1 shows the number of participants and survey responses obtained for both groups; On the day of the intervention, 15 students from the control group and 13 from the intervention group participated. In the control group, 13 filled the pre-survey, 8 filled the post-survey, and 8 girls filled both surveys. In the intervention group, 11 filled the pre-survey, 9 filled the post-survey, and 8 girls filled both surveys. Only the responses of the girls who filled out both surveys were used for the analyses.

The experimental design involved the random assignment of participants to either a control or intervention group. The topic of circuits was chosen because it is a fundamental concept covered in the Technology curriculum, which aligns with the academic curricula of Chile for this particular age group. Understanding circuits is crucial for students to comprehend the fundamental principles of technology and engineering, as it provides the foundation for the design and function of various electronic devices. By focusing on circuits, students can develop critical thinking and problem-solving skills while exploring the principles of electrical circuits, such as voltage, current, and resistance, which are essential to modern technology. Furthermore, understanding circuits is beneficial to students as it can lead to a greater appreciation of the impact of technology on society and the world around them.

The control group attended a conventional workshop that focused solely on the technical aspects of circuits, using a virtual circuits lab. This workshop followed a traditional epistemic education approach, without integrating any science content.

In contrast, the intervention group participated in a STEM workshop that integrated the concept of circuits with a science subject, using the STEM

Table 1: Responses to survey questions.

Group	Total Participants	Pre-survey	Post-survey	Responses to both surveys
Control	15	13	8	8
Intervention	13	11	9	8

virtual lab. The goal was to foster interdisciplinary learning and connect circuits with scientific concepts.

Both workshops followed a similar instructional format, beginning with an introduction to the task at hand and a discussion of how technology can support education. The existence and benefits of virtual labs were also explained, as some students had not previously used them. The instructor then delivered a didactic presentation, encompassing an introduction to circuits, a demonstration of how to navigate the interface, and an explanation of the fundamental properties of various components, including LED, jumpers, battery, resistance, and button. Also, the STEM workshop incorporated a Bunsen burner among its components. Moreover, both workshops were facilitated by the same female instructor, and relied on identical graphical design for on-screen instructions.

After the initial introduction, students in the control group were challenged to build a circuit to turn on an LED by pressing a button. Students in the STEM workshop were challenged to create a circuit to demonstrate how changes in states of matter from liquid to gas happen using an LED and a Button.

In the control group, students turned on an LED by connecting a resistance and a button to a battery. Every time they pushed the button, the light would turn on, indicating that the experiment was successful.

At the intervention group the students needed to develop a prototype that would increase the temperature of a beaker with water to reach the boiling point, applying engineering, electronics, and math concepts to assemble the prototype. Students press a button each time they want to turn on the LED, which increases the temperature of the water by 10ºC. The students must apply engineering concepts to decide how to build the prototype and electronics knowledge to turn on the Bunsen burner. Moreover, students use math to answer questions such as *How many grades more do we need to get to 100ºC? How many times do we have to push the button if every time we push it, the temperature increases by 10ºC?*

Both classes culminated with the same brief presentation on career paths within STEM, including information on the corresponding academic institutions.

4 RESULTS

Prior to conducting the experiment, a pre-survey was administered, and the results showed that both the intervention and control groups had a similar attitude toward science, which was higher than their attitude toward other STEM areas, as depicted in Figure 3. While the control group had a slightly better attitude toward math and technology, and the intervention group had a slightly worse attitude toward engineering, these differences were not statistically significant.

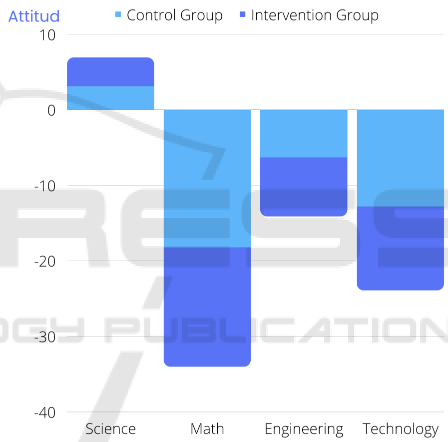

Figure 3: Pre-survey attitudes of control and intervention groups.

Following the intervention, another survey was administered to both groups, and the data was compared. The results indicated a significant improvement in the intervention group's attitude toward math, engineering, and technology, as depicted in Figure 4. In contrast, the control group showed no significant change in their attitude toward math or engineering, as illustrated in Figure 5. However, a slightly more positive attitude towards technology was observed, which could potentially be attributed to the use of the virtual laboratory or computer, as well as the application of circuits in the activity.

It is noteworthy that the intervention group demonstrated a slight improvement in their attitude towards math after the intervention, which was not observed in the control group. This finding is

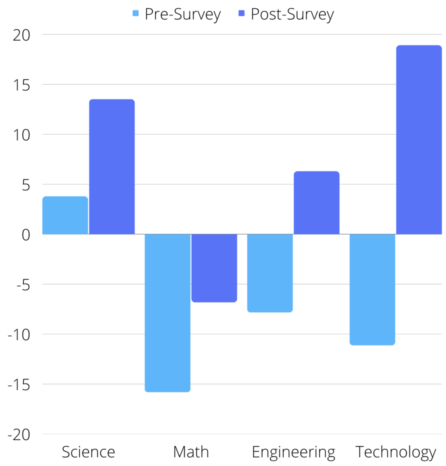

Figure 4: Change of attitude from pre to post survey in the intervention group.

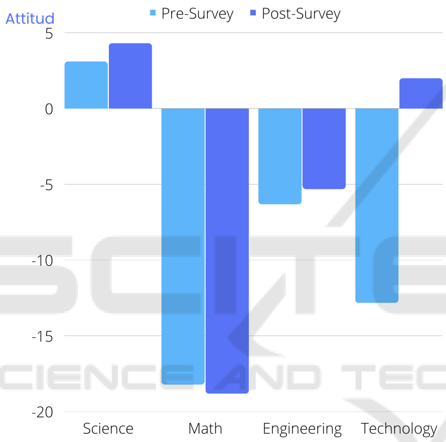

Figure 5: Change of attitude from pre to post survey in the control group.

particularly interesting as math is often viewed as a challenging subject, and any positive change in attitude towards it is a significant achievement.

One of the final questions in the survey asked participants about their future career choices, specifically whether they would like to pursue a career in science, engineering, or technology. The results showed that participants in the intervention group had a more positive disposition towards pursuing a career in engineering, science, and technology after the intervention, as depicted in Figure 6. In contrast, the control group only exhibited a more positive disposition towards pursuing a career in technology, as illustrated in Figure 7.

Finally the study found that students lacked knowledge about how STEM areas can work together. In the pre-survey, many of the girls responded with *"I am not sure"* when asked about this topic. However, after the intervention, we observed an improvement in this area, but only for the intervention group.

This finding may suggests that the STEM intervention was effective not only in improving students' attitudes and career aspirations but also in enhancing their understanding of how STEM areas can work together. This is an essential aspect of STEM education, as it encourages students to develop a more holistic and interdisciplinary approach to problem-solving. By demonstrating the interconnectedness of STEM areas, students are more likely to appreciate the importance of these fields and the significant role they play in shaping our world inspiring them to pursue a career in these areas.

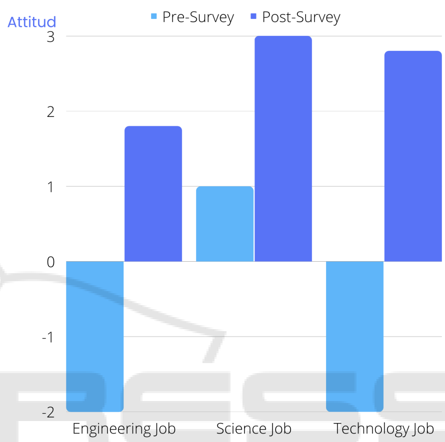

Figure 6: Change of attitude in the intervention group regarding future career.

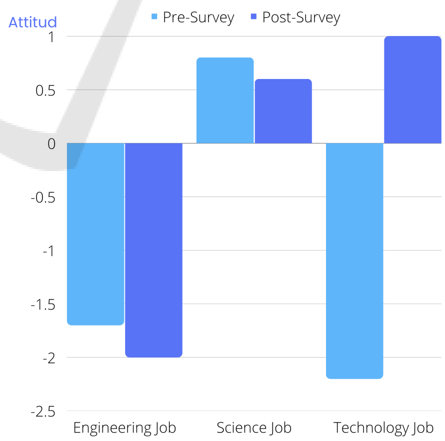

Figure 7: Change of attitude in the control group regarding future career.

5 CONCLUSION

This study proposes and assesses the efficacy of a science-based STEM virtual laboratory designed to encourage girls to explore STEM fields and narrow the gender gap in technology.

Overall, the STEM virtual lab offers a flexible, engaging, and interactive learning experience that empowers students to gain a deeper understanding of scientific concepts and principles. Through hands-on experimentation and problem-solving, students can develop the skills and knowledge necessary for future careers in technology.

The results of this study suggest that girls have a better attitude towards science than in other STEM areas before the intervention in both control an intervention group, which is consistent with the literature and confirm hypothesis (1). Girl's attitude towards engineering, math, and tech improved after the intervention, consistently with hypothesis (2). They also were more inclined towards a STEM career after the intervention, cording hypothesis (3).

The intervention of the STEM virtual lab resulted in a notable improvement in the students' understanding of how different STEM areas work together. Prior to the intervention, it was identified that there was a lack of knowledge in this area, which was subsequently addressed through the use of the virtual lab.

It's important to note that the STEM virtual lab is a valuable educational tool for both boys and girls. However, studies have shown that virtual labs can be particularly engaging for girls, as they provide a safe and supportive environment for them to explore STEM concepts and develop their skills.

The science based approach of this lab may help to break down gender stereotypes and encourage girls to pursue STEM careers by providing opportunities for them to engage in hands-on experimentation and problem-solving. However boys can use it and experiment its benefits as well, and further research is needed it.

6 LIMITATIONS AND FURTHER WORK

We would like to acknowledge the limitations of this work. The sample size was small and therefore results are not generalizable to other contexts. More research will be needed with a bigger cohort. We also used self-report as a measure of attitude towards STEM topics, while objective long-term data (such as actual career choices) would be preferable to draw solid conclusions.

Currently, the development of the STEM virtual lab is focused on incorporating coding capabilities, which will allow students of all genders to program and manage experiments using the platform. A longitudinal study with a larger sample of students is planned for the future to investigate the persistence of the observed change in attitude over time. In addition, to better understand the impact of novelty on students' attitudes, further research will be conducted to minimize its effect in future assessments. The novelty of using a virtual lab may be influencing students' attitudes, and this factor will be taken into account in the analysis of results.

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