Connecting Cultures through Computer Science: An Online International STEAM Initiative for Spanish speaking High School Students.

Mr. Marcelo Caplan, Independent Researcher

I am a former Associate Professor in the Science and Mathematics Department at Columbia College Chicago, with over 25 years of experience promoting STEM education in communities worldwide. Beyond my teaching responsibilities, I have actively worked to expand STEM learning opportunities in underprivileged communities.

My efforts include developing and implementing various community engagement programs, such as:

1. Scientists for Tomorrow – Co-Principal Investigator (Co-PI) of this NSF-ISE-funded initiative, aimed at integrating STEM learning into Out-of-School Time programs at community centers.

2. Junior Research Scientists Program – A program funded by After School Matters to support high school students in Chicago in conducting STEM research.

3. STEAM Learning Collaboration – Partnered with CCAS-NEIU to enhance STEM learning in the Upward Bound Math & Science program.

Additionally, I co-founded and co-chair the student-led STEAM Conference and established ManifiestoSTEAM, a collaborative initiative promoting STEM education in Spanish-speaking, underprivileged communities across Latin America. I also collaborate with international organizations such as the OEA and Virtual Educa.

Currently, I am developing a blended learning strategy to bring high-quality STEM education to remote and rural communities. This initiative aims to spark students' interest in STEM subjects and careers, fostering local talent and opportunities.

Aaron Cortes

Connecting Cultures through Computer Science: An Online International STEAM Initiative for Spanish speaking High School Students. (Evaluation)

Abstract

The STEAM Global Academy was established in 2020 amid the COVID-19 pandemic, initiated by the STEAM Pathways program from the Center of College Access and Success (CCAS) at Northeastern Illinois University (NEIU). This initiative provides high school students from Chicago and Latin America with informal education in computer science, utilizing the STEAM framework. Local students from Chicago are enrolled in the university's TRIO Upward Bound program, while international students receive sponsorship from local institutions or universities. All participants are Spanish speakers, and instruction is conducted in Spanish.

The primary objective of this initiative is to create a collaborative environment for adolescents from various backgrounds to engage in collective projects that tackle socially significant issues. The program features remote synchronous meetings every second Saturday for four hours, complemented by asynchronous work through a Learning Management System (LMS) on alternating weekends. When it comes to designing and implementing the prototypes for their final projects, participants from different countries establish their work protocols and complete their projects outside of regular meeting times, utilizing various communication tools.

Participant learning is concentrated on three primary domains: 1) Problem-solving utilizing microcontrollers (Arduino), 2) Developing mobile applications through MIT App Inventor, and 3) Leadership and teamwork skills. The duration of the program is one semester, generally comprising seven to eight synchronous sessions, culminating in a community presentation of final projects, where mentors and guest evaluators offer constructive feedback to the presenters. Throughout the program, participants undergo assessment via pre- and post-tests, leadership surveys, and evaluations of their projects.

This paper examines the outcomes of the Fall 2024 cohort, with a focus on the changes in participants' understanding of electricity, hardware, and computer science. Additionally, it explores the development of their teamwork skills and attitudes throughout the program.

The findings from the Fall 2024 implementation highlight the program's positive impact on participants' content knowledge, as evidenced by significant improvements in their comprehension of core concepts and practical applications. Participants demonstrated enhanced proficiency in working with microcontrollers, designing mobile applications, and applying their technical skills to solve real-world problems.

Moreover, the program fostered growth in critical teamwork skills, including collaboration, communication, and leadership. Participants reported increased confidence in working within culturally diverse teams, greater willingness to contribute ideas, and improved ability to navigate challenges collectively. These changes reflect the program's emphasis on creating a supportive and inclusive learning environment, where students can build both technical and interpersonal competencies.

1. Introduction

In today's interconnected world, the integration of technology into education has become paramount. This paper explores an innovative educational initiative aimed at teaching microcontrollers and mobile application design to high school students across Latin America and the United States via remote learning. By leveraging tools like Arduino and the MIT App Inventor, students work in small, multicultural teams to address real-world challenges, culminating in the development of social impact projects. This approach not only emphasizes technical skills but also fosters collaboration, creativity, and global awareness.

The Global STEAM Academy program from Northeastern Illinois University (NEIU) seeks to involve international youth in STEM by fostering discovery, observation, research, and practical application oriented to be involved and potentially solve problems of social impact in their region. The program is structured around eight bi-weekly synchronous sessions conducted via videoconference, supplemented by asynchronous learning through a Learning Management System (LMS). Each four-hour session is divided into three components: 90 minutes on foundational electricity and microcontroller use, 90 minutes on mobile application design, and 60 minutes dedicated to collaborative project work. The asynchronous tasks serve to reinforce these learning experiences, ensuring a continuous and cohesive educational journey.

This initiative aligns with contemporary educational paradigms that prioritize active, student-centered learning, particularly through methodologies like Project-Based Learning (PBL). The program's emphasis on collaboration, critical thinking, and the application of STEM (Science, Technology, Engineering, and Mathematics) concepts addresses the pressing need for engaging and equitable educational opportunities in a globalized context. The following sections provide a comprehensive analysis of the theoretical framework, methodology, and outcomes of this last implementation of the program Fall 2024 between September to December 2024.

The program was first implemented in Spring 2020 in response to the challenges posed by the COVID-19 pandemic to the education system. Following its initial success and at the request of international partners, the program has continued with the voluntary support of the researchers. Notably, this initiative does not receive external funding, relying solely on in-kind contributions from the university, such as access to its facilities and internet services. Overall, it remains a voluntary project that evolves and grows based on the time and resources available.

2. Literature Review

2.1 Project-Based Learning (PBL)

Project-Based Learning (PBL) is a student-centered pedagogical approach that involves learners in real-world problem-solving tasks. PBL has proven effective in enhancing technical and soft skills, fostering deeper understanding, and promoting intrinsic motivation [1]. Key elements of successful PBL include centrality, collaboration, and constructive investigations, all of which are integral to the program's design. Studies highlight that PBL can bridge the gap between theoretical knowledge and practical application, particularly in STEM education [2].

Key Attributes of PBL:

1. **Student-Centric Learning:** Students actively direct their learning process, enhancing autonomy and relevance [11].
2. **Skill Development:** PBL promotes 21st-century competencies—critical thinking, collaboration, communication, and creativity [12].
3. **Interdisciplinary Approach:** Projects integrate multiple disciplines, fostering a holistic understanding of complex issues [13].
4. **Collaboration:** Group work enhances social skills and knowledge retention through peer interaction 14].
5. **Authentic Assessment:** Evaluation focuses on tangible outcomes and reflective processes, encouraging metacognitive skills [15].

Challenges in PBL Implementation: Despite its benefits, PBL presents several challenges:

- **Planning Complexity:** Teachers need to design projects that align with learning objectives and remain feasible within available resources [11].
- **Resource Constraints:** Limited access to materials and technology can hinder project execution, particularly in under-resourced rural areas [15].
- **Teacher Training:** Effective facilitation requires training in fostering autonomous and collaborative learning environments [11].

In computer science, PBL encourages students to design, develop, and test software or hardware solutions to complex problems. For instance, students can collaborate on projects such as creating mobile apps that solve specific community issues or programming robotic systems for automation. These projects not only enhance computational thinking but also cultivate teamwork and communication skills [3]. PBL fosters a deeper understanding of abstract concepts by grounding them in tangible, real-world applications. For example, implementing algorithms for data sorting or artificial intelligence in practical scenarios allows students to see the direct impact of their work.

Additionally, PBL in computer science often integrates interdisciplinary approaches. Projects may combine elements of mathematics, physics, and design, encouraging students to view problems from multiple perspectives. The iterative nature of PBL—where students define a problem, prototype solutions, and refine their work based on feedback—closely mirrors industry practices, preparing students for future careers.

2.2 Remote Education

Remote education expands access to learning by eliminating geographical and infrastructural barriers [9]. Remote education is a virtual learning format used in emergencies, often without extensive planning [16]. The COVID-19 pandemic accelerated its adoption due to mobility restrictions [17]. Unlike distance education, which is systematically designed, remote learning is reactive [18] [19].

Hybrid Learning Model

Remote education has evolved into hybrid learning, integrating face-to-face and virtual environments. Hybrid learning intentionally combines both modalities for flexibility and engagement [4]. Synchronous and asynchronous methods enhance accessibility and self-paced learning. Tools like Moodle and Zoom facilitate collaboration and personalized instruction [19].

Challenges and Strategies

Challenges include the digital divide and reducing social interaction, impacting student motivation [20] [16]. Effective strategies include active learning methodologies, project-based learning, gamification, and continuous teacher training [4] [19].

Key Attributes and Future Considerations

Hybrid education offers flexibility, global resource access, and pedagogical innovation [20]. To ensure its effectiveness, reducing digital disparities, continuous faculty development, and student-centered approaches are essential [16] [19]. Hybrid learning can enhance education beyond emergencies with proper planning and investment.

2.3 Engaging High School Students in Collaborative Work

Collaboration is a cornerstone of 21st-century education, fostering critical skills such as communication, empathy, and teamwork. Maggiore et al. [3] emphasizes the importance of challenging, authentic tasks in engaging high school students in collaborative work. High school students are more likely to be engaged when the learning process involves problem-solving that mirrors real-world scenarios. Authentic challenges, like designing mobile apps for community support or developing systems to optimize energy use, are particularly effective in stimulating student interest.

According to the findings by Pang et al. [5], engaging students through collaborative work requires more than simply assigning group tasks; it involves providing tools and frameworks that empower them to evaluate both the positive and negative impacts of their projects. This not only enhances their technical abilities but also nurtures a sense of social responsibility. Tools like the computational action toolkit help students analyze the ethical implications of their designs, fostering a deeper connection between their work and societal outcomes. The Computational Action Toolkit provides structured tools to guide students through problem-solving, design, and project management. It includes:

- Ideation Tools: A mind map for brainstorming meaningful problems.
- User Research Tools: Templates for user research, user personas, and a collaborative analysis framework.
- Design and Impact Tools: An impact matrix, a feature of importance vs. cost tool, and wireframing tools.

- Project Management Tools: A teamwork task management table and a project management board.
- Reflection and Planning Tools: A project reflection matrix and a future timeline plan.

These tools help students systematically explore problems, analyze user needs, design solutions, manage teamwork, and reflect on their projects.

Pang et al. [5] further highlights that students are more motivated when they are given autonomy to define problems relevant to their contexts and communities, which align with the principles of PBL.

The program's structure—pairing students from different cultural and national backgrounds—also serves as a platform for developing intercultural competence. When students work collaboratively in diverse teams, they learn to navigate differences in perspectives and approaches, which mirrors real-world professional environments. By fostering an inclusive learning culture, this model prepares students for global citizenship.

2.4 Benefits of Learning Computer Science in High School

Early exposure to computer science has significant long-term benefits, including improved problem-solving abilities, heightened creativity, and better preparedness for future careers [10]. Learning computer science at a young age fosters computational thinking, a critical skill for tackling complex problems across disciplines [1].

Moreover, tools like MIT App Inventor make programming accessible, reducing barriers for beginners [6]. By enabling students to design functional and impactful applications, such tools inspire confidence and creativity, particularly among underrepresented groups in STEM. According to Dema and Choden [2], students who engage in computer science early often show greater interest in STEM careers, as they can directly link their learning to tangible societal improvements.

Computer science also promotes collaboration through team-based projects, where students learn soft skills like communication and leadership. Collaborative environments enhance engagement and prepare students for interdisciplinary teamwork [5]. High school programs focused on computer science often serve as gateways to advanced studies, equipping students with foundational skills that align with industry demands. Additionally, exposure to programming and problem-solving during formative years cultivates adaptability, a valuable trait in today's rapidly evolving technological landscape.

3. The Global STEAM Academy program

3.1 Methodology

The Global STEAM Academy's design is grounded in best practices for remote, collaborative, and project-based STEM education. It employs a mixed-methods approach to evaluate its effectiveness, combining quantitative metrics (e.g., pre- and post-tests) with qualitative data (e.g., student reflections and project outcomes). Given that the population involved in the program are Spanish speakers, all the material presented in the program is in Spanish as well as the instruction. Two university faculty with background in electrical engineering, computer science, and Spanish as their mother tongue, are the instructors and leaders of the program.

3.1.1 Participants

The program involves high school students from diverse socio-economic and cultural backgrounds across Mexico, Colombia and United States. The students from the United States are participating in the program Upward Bound from the Northeastern Illinois University (NEIU). These students are first generation non privileged that speak fluently Spanish and English.

Participants are invited to join the program via their mentors from the local organizations. They need to complete the application process that assesses their interest in STEM and their commitment to collaborative learning and willingness to participate in this FREE program. The program is offered at not cost for the local and international participants.

3.1.2 Program Structure

The program aims to empower international youth to collaborate on developing projects that address socially impactful problems within their local communities. Through this process, students not only gain STEM knowledge in electricity, microcontrollers, and mobile application design but also cultivate 21st-century skills, such as communication, collaboration, and leadership, as outlined by the World Economic Forum (2016). These essential abilities are actively fostered throughout the program.

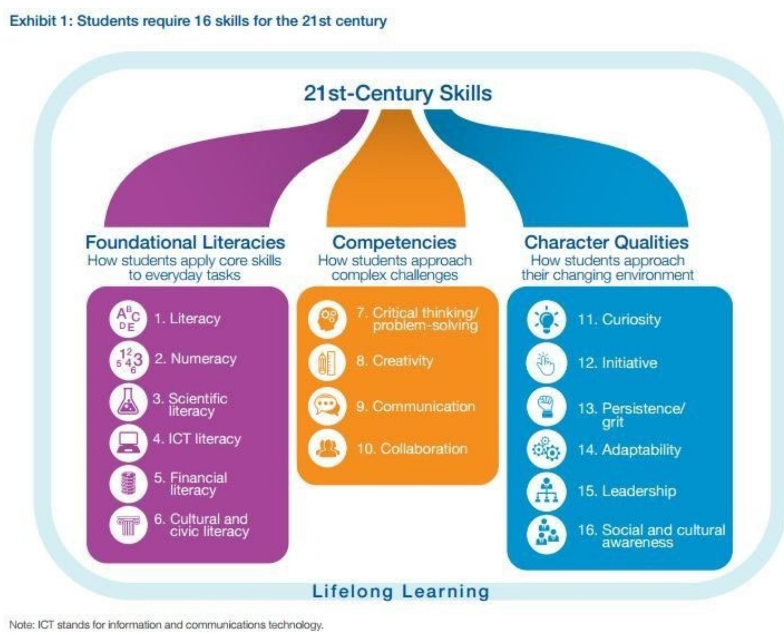

Figure 1. 21st century skills. Image: World Economic Forum, New Vision for Education (2015)

The program includes eight synchronous meetings presented in Table 1, asynchronous independent work between the synchronous meetings as shown below.

Table 1: Schedule of the activities of the Electricity and Microcontrollers workshops

Week	Activity Description
1	Project introduction - Orientation and logistics - a first collective interaction - Introduction to Tinkercad. Basic electricity to solve problems using the Arduino microcontroller
2	Introduction to Arduino - Microcontroller fundamentals - Digital inputs and outputs - My first circuit and program
3	Digital inputs using a switch - Solving problems with information from the outside world
4	Exploring Outputs with PWM - Pulse Width Modulation. How does Arduino produce an “almost analog” output? Introduction to project generation
5	Exploring Analog Inputs - How does Arduino understand continuous values? Conversion from Analog to Digital
6	Manipulating information using numerical variables. Using sensors to understand the real world; Light, Temperature, Distance sensors, and others
7	How to activate objects that require a lot of power? The use of Drivers. Introduction to stepper motors - STEP MOTOR, How does Arduino know where the motor is without having any information? Definition of the final project
8	Project Presentations

1. **Synchronous Sessions:** Conducted every two weeks via Zoom. The day of the meeting was Saturday, and therefore each participant joined the videoconference using their personal device from their available location. These sessions include:

    - **Electricity and Microcontroller Workshop (90 minutes):** Interactive, hands-on tutorials provide students with practical experience using Arduino microcontrollers, sensors, and actuators. These sessions guide participants through the fundamentals of circuit design, sensor integration, and actuator control, enabling them to build and test functional prototypes. The tutorials are designed to reinforce theoretical knowledge through real-world applications, fostering problem-solving skills and creativity.

    - **Mobile Application Design (90 minutes):** Structured and engaging exercises in MIT App Inventor provide students with a step-by-step introduction to designing and programming mobile applications. These guided activities empower participants to create user-friendly apps, integrate advanced functionalities, and connect their apps to external hardware, such as sensors and actuators. By focusing on practical, real-world scenarios, the exercises enhance computational thinking, creativity, and problem-solving abilities while building confidence in programming.

- **Social Impact Project Development (60 minutes):** Collaborative small-group sessions are dedicated to identifying and addressing pressing social issues within local and global contexts. Students work together to brainstorm, research, and define problems relevant to their communities, fostering critical thinking and empathy. These sessions emphasize teamwork and innovative problem-solving as participants design actionable solutions, often integrating technology to create meaningful social impact.

2. **Asynchronous Tasks:** Hosted on the free LMS platform Canvas, these asynchronous tasks are thoughtfully designed to complement and reinforce the concepts covered during synchronous sessions. They include interactive quizzes to test knowledge retention, dynamic discussion forums to foster peer collaboration and idea exchange, and clearly defined project milestones to guide students through their hands-on learning journey. This structure ensures continuous engagement and provides a flexible learning environment that supports individual and group progress.

Final Projects: Each team delivers a fully functional prototype that addresses a real-world problem, seamlessly integrating hardware and software components. These prototypes demonstrate the practical application of STEM concepts, showcasing the team's ability to design, program, and implement innovative solutions. The process emphasizes creativity, technical proficiency, and collaboration, culminating in tangible projects that have the potential to make a meaningful social impact. At the last meeting of the program, the groups presented their projects to all the Global STEAM Academy community via a live videoconference.

3.1.3 Data Collection and Evaluation

To gauge the effectiveness of the program, the leadership used two instruments to collect data: 1) a content knowledge test based on Electricity, Basic hardware knowledge, and basic programming skills and 2) a survey about teamwork. The content knowledge test was applied in the modality pre and post test, to gauge the impact of the intervention, when the Teamwork survey was taken the last day of the program to collect information regarding the impressions of the participants in their experience working with other teens remotely.

The content knowledge test was designed by the instructor that designed the section of the program regarding electricity and microcontrollers. Below is the schedule and the topic presented in the course used to design the instrument. The instrument includes 23 multiple choice items, with four choices per item, with only one correct answer.

To validate the test, the validation process outlined in Coral [7], was followed. The test was checked for its face and content validity by two experts in the topic. Both experts are fluent in Spanish. The participants completed this test in the first and last meeting of the program. For the next time the leadership will implement this Global STEAM academy, the program will develop a mobile applications content test to also gauge the grow of the students in this area.

The teamwork survey was adapted from an existing survey - Group interaction behaviors that affect performance on an intellective task from Watson, W.E. & Michaelsen, L.K. [8]. The survey was translated into Spanish and checked for face validity for two experts fluent in Spanish. The participants completed this survey the last day of the program

Regarding the final project presentation, in this implementation the program only considers the completion of the task as fulfilling the objective of the program. It is necessary for futures implementations to develop clear rubric for the objective assessment of the final projects presented by the students.

4. Evaluation of the implementation of the Global STEAM Academy – Fall 2024

Overview of the evaluation process

In the weeks previous of the initial synchronous meeting (September 28, 2024) the leadership team contacted the potential partners to invite them to participate in the project and to enroll their students in the LMS Canvas before the first meeting. Despite all the efforts in the leadership team side, giving that for many of the partners is "an additional work", and that the program es free and do not have an impact in the participants, many students did not complete the enrollment on the platform until later, missing the pretest.

Then several students quit the project before the final project, and several students joined the project after the first week, therefore although there is a large number of students that completed the pre and posttest, only 21 students completed both the pre and posttest.

Following is the analysis of the data collected during the project

4.1 Quantitative analysis of the content knowledge test

4.1.1 Data analysis of the pretest taken the first week of the program

The pretest was taken by 59 students: 22 females and 37 males from three countries, Colombia 54 students, Mexico 1 student and USA 4 students. The frequency of the age of the students is presented below.

Table 2. Students' Age that took the Pre-Test

Students' Age

		Frequency	Percent
Valid	13	7	11.9
	14	3	5.1
	15	11	18.6
	16	12	20.3
	17	10	16.9
	18	16	27.1
	Total	59	100.0

The presented 59 students that completed the pretest obtained a mean score of 11.49 of 23 points and a standard deviation of 3.89

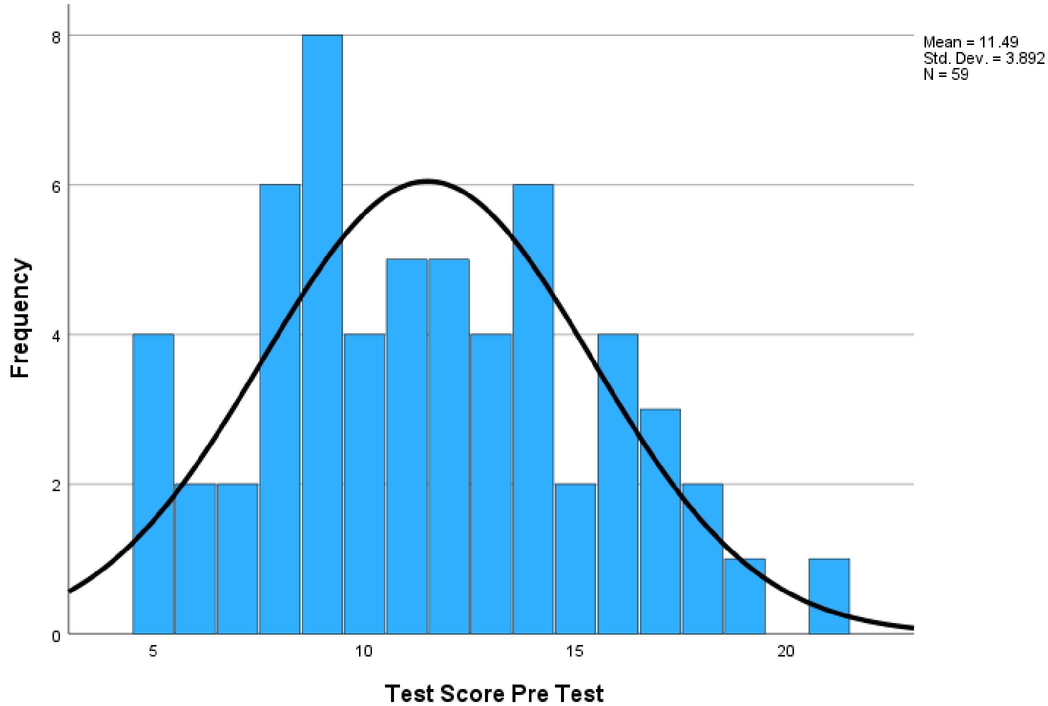

Figure 2. Distribution of the results of the Pre-Test taken by participants N=59

4.1.2 Data analysis of the posttest taken the last week of the program

The posttest was taken by 42 students: 18 females and 24 males from three countries, Colombia, 21 students, Mexico, 16 student and USA, 5 students. The frequency of the age of the students is presented below

Table 3. Students’ Age that took the Post-Test

Students' Age

		Frequency	Percent
Valid	13	1	2.4
	14	1	2.4
	15	7	16.7
	16	9	21.4
	17	13	31.0
	18	11	26.2
	Total	42	100.0

The presented 42 students that completed the pretest obtained a mean score of 16.38 of 23 points and a standard deviation of 3.903

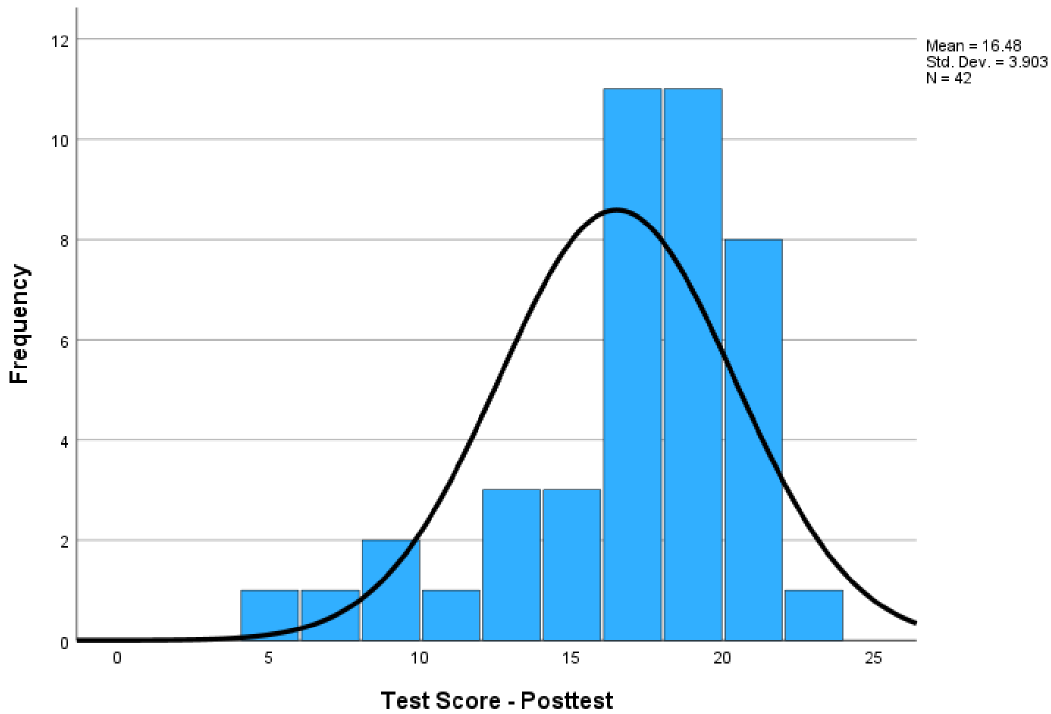

Figure 3. Distribution of the results of the Post Test taken by participants N=42

4.1.3 Data analysis of the pre and posttest of all the participants

Since many students who completed the program did not take the pretest, one way to evaluate the program's effectiveness is by comparing the changes in the means of the group that took the pretest with those of the group that took the posttest. Assuming the students are distinct individuals in similar conditions, this comparison can be conducted using an independent sample t-test.

Table 4. Independent T Test results between the groups that took the Pre and Post Test

Group Statistics

	pre/post	N	Mean	Std. Deviation	Std. Error Mean
Score	Posttest	42	16.4762	3.90271	.60220
	Pretest	59	11.4915	3.89240	.50675

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					
						Significance			
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference
Score	Equal variances assumed	.521	.472	6.336	99	<.001	<.001	4.98467	.78669
	Equal variances not assumed			6.333	88.319	<.001	<.001	4.98467	.78704

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
Score	Cohen's d	3.89667	1.279	.843	1.710
	Hedges' correction	3.92651	1.269	.836	1.697
	Glass's delta	3.89240	1.281	.818	1.735

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

An independent sample t-test was conducted to determine if there was a difference in test scores between students who participated in pretest and those who participated in the posttest.

The analysis showed that the mean score for the pretest group ($M=11.49$, $SD=3.89$) was significantly lower than the mean score for posttest group ($M=16.47$,$SD=3.9$), $t(99)=6.33$,$p<0.001$. This indicates that students who participated in the program have a significative high score in the test.

The effect size, calculated as Cohen's d, was 1.279, suggesting a large difference between the groups. This result implies that the program had a substantial positive impact on student performance.

The histogram below presented in Figure 4, illustrates the score distributions for the pretest and posttest groups, providing a visual comparison of their mean differences along with the homogeneous distribution curve.

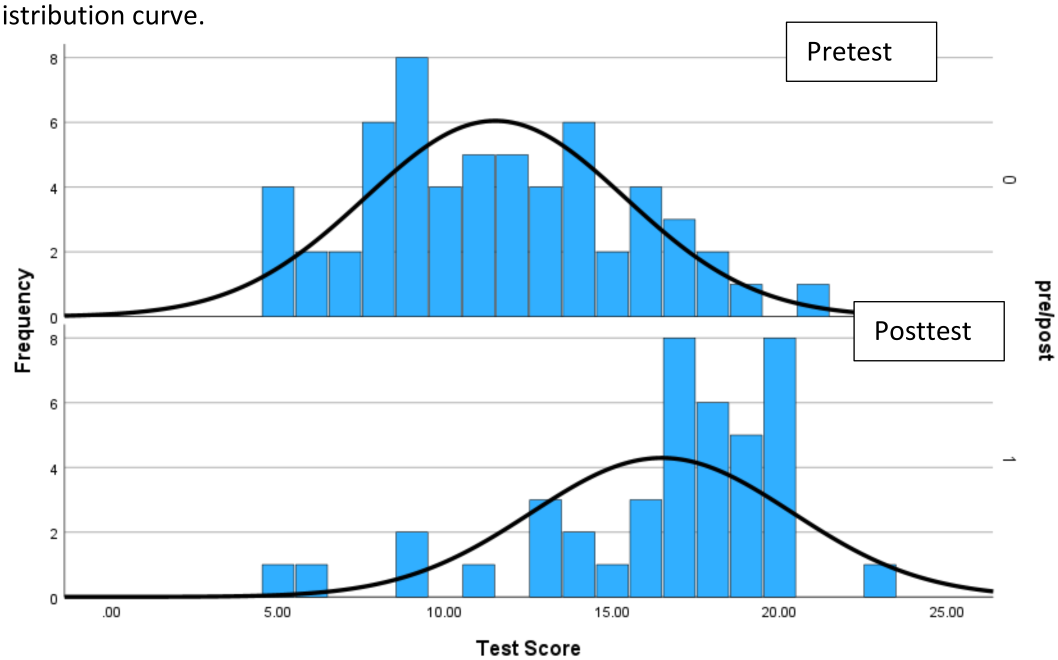

Figure 4. Visual comparison of the score distributions of the Pre and Post Test.

4.1.4 Data analysis of the pre and posttest of the participants that completed valid pre and posttest

Of the students who participated in the program, 20 completed both the Pre and Post Test with valid responses N=20. A paired sample T-test was conducted to assess the impact of the intervention on this group.

Table 5. Paired T Test results of the group that completed valid Pre and Post Test N=20

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Post	17.00	20	3.699	.827
	Pre	10.20	20	3.736	.835

group.

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	Post - Pre	6.800	3.488	.780	5.167	8.433	8.718	19	<.001	<.001

Paired Samples Effect Sizes

					95% Confidence Interval	
			Standardizer	Point Estimate	Lower	Upper
Pair 1	Post - Pre	Cohen's d	3.488	1.949	1.185	2.696
		Hedges' correction	3.634	1.871	1.138	2.588

The results of the content knowledge test before the intervention for this group were M1=10.20 , SD=3.736, and after the intervention were M2=17, SD=3.699. The paired t-test revealed a significant difference between the conditions, $t(19)=8.718$, $p<0.001$. Therefore, we reject the null hypothesis and conclude that the intervention significantly improved the participants' content knowledge.

The effect size, calculated as Cohen's d, was 1.94, suggesting a large difference between the groups. This result implies that the program had a substantial positive impact on student performance.

The graph plotted below shows in a visual way that ALL the participants that completed the program increased their test scores.

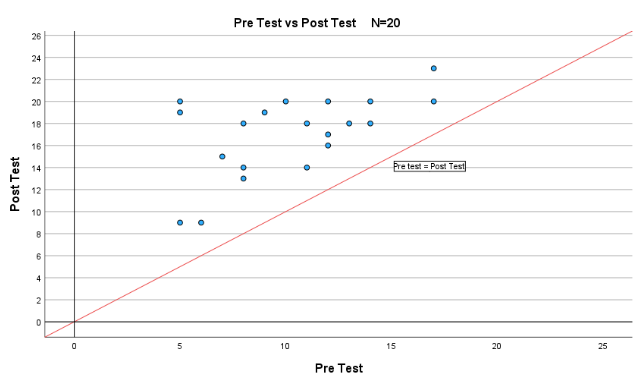

Figure 5. Visual comparison of the score of individual students – Pre vs. Post

To conclude this section, the results of the analysis indicate that the intervention had a positive effect on the participants' content knowledge.

4.2 Analysis of the teamwork survey

4.2.1 Quantitative analysis

At the last meeting of the program, the participants completed the teamwork survey that included quantitative and qualitative items designed to gauge the self-impression of the participant when working with his/her team. Thirty-five students completed the survey N=35

The quantitative section of the survey consists of 11 statements, each rated on a Likert scale where 5 indicates "To a very great extent," 4 indicates "To a great extent," 3 indicates "Sufficient," 2 indicates "To a little extent," and 1 indicates "To a very little extent."

Table 6 presents a summary of the quantitative statements, and the means of the answers collected. The numbers in red indicate they are negative statements

Table 6. Summary of the quantitative statements and the means of the answers collected

Statement	Mean
We work together.	3.77
There is a group concern for the quality of performance.	3.40
We share high-performance expectations.	3.97
Some people take our group work too lightly.	2.69
Some team members with good ideas do not speak up.	2.17
Some group members avoid disagreement out of fear.	1.83
One or two members tend to dominate the discussion.	2.86
We listen to each individual's contributions.	4.43
Team members feel free to provide constructive comments.	4.17
There is a climate of trust in our group.	3.91
We feel comfortable with the roles we play in the group.	4.17

The data collected reveals both strengths and challenges in students' group work dynamics. Positive aspects include active collaboration, with students listening to each other's contributions (4.43) and feeling free to provide constructive feedback (4.17). Groups generally experience trust (3.91) and comfort with assigned roles (4.17), fostering a supportive environment. Shared expectations for high performance (3.97) also highlight a focus on achieving group goals.

However, challenges emerge in areas related to communication and participation. Statements such as "Some team members with good ideas do not speak up" (2.17) and "Some group members avoid disagreement out of fear" (1.83) indicate barriers to open communication and conflict resolution. Additionally, perceptions that "Some people take our group work too lightly" (2.69) and "One or two members tend to dominate the discussion" (2.86) suggest uneven contributions, which could impact group productivity and morale.

Moderate scores for "We work together" (3.77) and "There is a group concern for the quality of performance" (3.40) suggest room for improvement in overall cohesion and accountability.

4.2.2 Quantitative analysis

The qualitative section of the survey includes 4 open questions: 1) What did you like the most about working with your team? 2) What did you like the least about working with your team? 3) Describe at least three things that worked well in your team, and 4) Describe what things have NOT worked well in your team.

In response to the question, "What did you like the most about working with your team?" students provided 35 responses. From these, the following constructs were identified. Below is the expanded list with examples included for each construct:

- **Collaboration (5 voices)**
  This construct reflects the team's ability to work together in an organized manner, dividing tasks equitably and ensuring that each member contributes according to their skills. It includes aspects such as reaching agreements and motivating one another to complete the work effectively.
  Example: "We were able to divide the tasks fairly, and everyone had the opportunity to contribute according to their strengths."
- **Communication (4 voices)**
  Effective communication emerges as a key element in facilitating teamwork. It refers to the fluid exchange of ideas, opinions, and messages that enable coordination and problem-solving, as well as the effort to maintain constant dialogue to achieve goals.
  Example: "It was easy to understand each other and come to an agreement quickly to complete the project."
- **Contribution of Ideas (4 voices)**
  This construct highlights the importance of creative and valuable ideas contributed by team members. It emphasizes how these ideas are considered and valued by the group, creating a more enriching and collaborative work environment.
  Example: "The creative ideas everyone contributed were valuable and always taken into account."
- **Diversity and Perspectives (4 voices)**
  This highlights the value of working with people from different cultural or geographic contexts. Diversity allows for new ways of thinking and unique perspectives, enriching the creative process and fostering a better understanding of how to approach tasks and challenges.
  Example: "Working with people from different countries allowed us to share unique perspectives and successfully complete the project."
- **New Personal Connections (4 voices)**
  This construct underscores how teamwork facilitates meeting new people, building bonds, and discovering common interests. It includes the opportunity to connect with colleagues

from different regions or countries and to form deeper relationships during the process. *Example:* "Getting to know new people from other parts of the world and discovering shared interests was the most enjoyable part of teamwork."

In response to the question, "What did you like the most about working with your team?" students provided 35 responses. From these, the following constructs were identified, each illustrated with examples:

- **Positive Experiences (5 voices)**
  This construct reflects participants who had overall satisfying and harmonious experiences while working with their team. It includes feelings of smooth collaboration, effective communication, and overall contentment with the teamwork process.
  Example: "Everything went well; I didn't find anything I didn't like. It was a calm and productive experience."

- **Lack of Participation (4 voices)**
  This construct highlights challenges related to team members not contributing to the project or being unresponsive. It reflects dissatisfaction with the uneven distribution of effort, where some team members felt unsupported.
  Example: "Most of the team didn't contribute; some didn't even reply to messages or show up for the meetings."

- **Time Management (4 voices)**
  This construct emphasizes difficulties in organizing meetings or working on tasks due to personal schedules, time constraints, or external commitments. It points to the challenge of aligning team availability for efficient collaboration.
  Example: "It was hard to coordinate because everyone had different schedules, and it was difficult to find a time to meet virtually."

- **Communication Challenges (3 voices)**
  This construct represents obstacles in maintaining effective communication among team members. Issues such as unanswered messages, misunderstandings, or lack of clarity in communication hindered teamwork.
  Example: "The communication was complicated; some members didn't respond, which made it hard to move forward as a team."

- **Effort and Division of Tasks (3 voices)**
  This construct addresses issues related to unequal effort or responsibility distribution among team members. It includes frustration with members who procrastinated or left the bulk of the work to a few individuals.
  Example: "Some team members left things for the last minute, and my partner and I had to complete most of the project ourselves."

In response to the prompt, "Describe three things that worked well with your team," students provided 35 responses. From these, the following constructs were identified, each accompanied by examples:

- **Communication (6 voices)**
  This construct reflects the importance of clear, respectful, and effective communication within the team. It includes aspects such as active listening, consistent interaction (via chats or calls), and creating an environment where everyone feels comfortable sharing their opinions and ideas.
  Example: *"From the very first day, we created a group chat and maintained assertive communication throughout. Everyone worked hard and adjusted to each other's schedules, even if they were complicated."*

- **Organization and Task Division (4 voices)**
  This construct emphasizes the role of planning, dividing tasks based on members' strengths, and integrating individual contributions into the collective effort. It highlights teamwork strategies like role assignments and systematic coordination.
  Example: *"The organization was excellent. Tasks were divided based on each person's skills, and we successfully integrated individual contributions into the final project."*

- **Creativity and Problem Solving (4 voices)**
  This construct highlights the creative input and collaborative problem-solving efforts within the team. It includes generating ideas, leveraging members' skills, and resolving challenges collectively to achieve project goals.
  Example: *"We brainstormed together and shared ideas creatively. Everyone's prior knowledge, especially in programming, helped solve problems and enhanced our project quality."*

- **Effort and Motivation (4 voices)**
  This construct focuses on the dedication and positive attitude of team members. It includes the motivation to contribute, responsibility toward completing tasks, and mutual encouragement to stay committed to the project.
  Example: *"Everyone showed enthusiasm and dedication. The positive attitude and willingness to work hard made the process enjoyable and successful."*

In response to the prompt, "Describe three things that did not work well with your team," students provided 35 responses. From these, the following constructs were identified, each accompanied by examples:

- **Communication Challenges (4 voices)**
  This construct reflects difficulties in maintaining effective communication among team members. It includes issues like lack of clarity, delayed responses, or challenges in organizing meetings due to differing schedules or time zones.
  Example: "It was quite challenging to organize meetings because of the time zone differences and some members' availability. Although we managed to adapt, it required a lot of effort."

- **Time Management Difficulties (4 voices)**
  This construct addresses problems related to poor time management, including tight schedules, punctuality issues, and insufficient time to complete tasks. It highlights the impact of these challenges on the progress of the project.

Example: "Time management was an issue. Some members struggled with punctuality and coordinating their schedules, which delayed certain parts of the project."

- **Task Division Problems (4 voices)**
  This construct points to inefficiencies in dividing tasks among team members. It includes a lack of clear role assignments, uneven workload distribution, and difficulties in ensuring all tasks were completed effectively.
  Example: "The task division was not well-structured, and some team members ended up doing most of the work while others contributed very little."

- **Participation Issues (2 voices)**
  This construct highlights the lack of active engagement or contribution from certain team members. It reflects frustration with team members who did not respond, participate, or show commitment to the project.
  Example: "Some members didn't participate at all. They didn't even respond to group chats or make an effort to join discussions."

Summary of the qualitative analysis

The analysis reveals key factors that contribute to successful teamwork, including collaboration, communication, and clear task division. When teams effectively coordinate, actively participate, and integrate diverse perspectives, they experience smoother interactions and achieve better outcomes. Structured organization, well-defined roles, and open dialogue foster creativity, problem-solving, and motivation. Additionally, working with individuals from different backgrounds enhances learning, making teamwork more enriching and dynamic.

However, challenges such as lack of participation, time management issues, and communication barriers negatively impacted some teams. Frustration arose from unresponsive members, uneven workload distribution, and scheduling conflicts, leading to inefficiencies. These issues highlight the need for clear expectations, accountability, and structured coordination. Strengthening communication strategies, promoting responsibility, and establishing shared guidelines can improve teamwork, ensuring equitable contributions and a more positive experience for all members.

5. Challenges in the implementation of the program

The program faces several challenges that may hinder its effectiveness and long-term success. A key issue is the lack of tangible incentives for participation. Since the program relies entirely on self-motivation, participants who lack intrinsic interest or face competing priorities may struggle to remain engaged. Without external motivators, such as rewards, certifications, or recognition, maintaining commitment becomes challenging, especially for younger participants who might require additional encouragement.

Another obstacle is the timing of the program. Conducting sessions on Saturdays, outside of the standard school schedule, places additional demands on participants' free time. For many, weekends are reserved for rest, family, or extracurricular activities, making it harder to prioritize attendance. This scheduling may inadvertently lead to lower participation rates or inconsistent attendance.

Additionally, the program's outcomes lack immediate or significant impact on the participants' lives. If a participant chooses to quit midway or fails to present a final project, there are no meaningful consequences. This lack of accountability may lead to a perception that the program's value is limited, reducing the motivation to complete it or achieve its objectives.

Lastly, the free nature of the program poses a challenge for partner organizations. Since there is no financial investment, partners might not feel compelled to ensure that their students complete the program. Without a sense of shared responsibility, partner organizations may treat the program with less urgency or commitment, further impacting participant engagement.

In summary, the program's reliance on self-motivation, its challenging schedule, the lack of immediate consequences for non-completion, and the absence of financial accountability for partners are significant hurdles. Addressing these issues through strategic adjustments—such as introducing incentives, improving scheduling, and fostering shared responsibility—could enhance participant engagement and program outcomes.

6. Final projects presentations

The participants of the cohort Fall 2024 were divided into eight teams to propose a problem of social impact in their communities and then design and develop a prototype that can be a potential solution to the presented problem. Giving the time limitations of the program, the team produced a first approach to solve the selected problem using microcontrollers, mobile applications or both.

The following are some examples of the projects developed by the students:

The "Food for All" Project

The "Food for All" app connects food providers (restaurants and businesses) with consumers (community centers and individuals in need) to reduce food waste and improve distribution. Businesses post leftover food availability on the app, allowing community centers to collect and redistribute it. In return, participating in businesses gain tax benefits and promotional opportunities.

The app, developed using MIT App Inventor, features two interfaces: one for providers to log food donations and one for consumers to organize collections. Providers gain visibility through a ranking system based on donation frequency. Campaigns and signage outside businesses raise awareness of participation. This initiative promotes food sustainability and supports vulnerable populations.

The "Vital Care" Project

The "Vital Care" app connects older adults with potential caregivers to address challenges like limited access to personalized services, social isolation, and lack of support in daily tasks. Recognizing that families often lack time and resources, the app provides an organized, accessible solution. It is designed to be visually appealing and user-friendly, ensuring ease of use for all. The initiative emphasizes its significant social impact and demonstrates its purpose through step-by-step guidance, showcasing how the project was developed to improve the quality of life for older adults and support their caregivers.

The “Reuse App” Project

The Reuse App promotes recycling by enabling users to exchange unused items with others who value them, fostering a barter-based economy. Inspired by the idea that "one man's trash is another man's treasure," the app aims to: (1) encourage recycling through rewards, (2) help users locate nearby recycling points using a virtual map, and (3) raise environmental awareness through educational data and statistics. The app features two sections: one for publishing items available for exchange and another for browsing existing offers. This initiative seeks to build sustainable habits and reduce waste while connecting people through shared resources.

All projects were showcased on the final day of the program through a videoconference attended by participants, their parents, and mentors, providing an opportunity to view the teams' work. Each team was allocated 7 minutes to present their project. Teams prepared their presentations using the media format of their choice and ensured all members participated in delivering the presentation. Following each presentation, a dedicated Q&A session allowed interaction and feedback.

7. Conclusion

The Global STEAM Academy program demonstrates significant potential to foster technical, collaborative, and creative skills among high school students from diverse cultural and socio-economic backgrounds. By integrating the teaching of microcontrollers and mobile application development with leadership and teamwork training, the program equips participants with critical 21st-century skills while addressing socially relevant issues. The positive impact of the initiative is evidenced by significant improvements in students’ content knowledge, as demonstrated through both pre- and post-test evaluations, with large effect sizes underscoring the effectiveness of the intervention.

Collaboration within culturally diverse teams further highlights the program's strengths, with participants reporting active engagement, trust, and constructive feedback in their teamwork experiences. However, the survey data also underscores challenges related to communication, participation, and task management, emphasizing the need for enhanced support mechanisms to address these obstacles. Encouraging inclusivity, fostering open communication, and promoting equitable contributions remain critical to maximizing the program’s impact.

Despite its strengths, the program faces logistical and structural challenges. The reliance on self-motivation without incentives, the weekend scheduling, and the lack of immediate consequences for incomplete participation pose risks to sustained engagement. Moreover, the free nature of the program may limit accountability among partner organizations, affecting participant consistency. Addressing these issues through the introduction of tangible incentives, more flexible scheduling, and shared responsibility among stakeholders can further strengthen the initiative.

In conclusion, the Global STEAM Academy exemplifies a forward-thinking approach to remote STEM education by blending technical learning with social impact. While its achievements in fostering knowledge and collaboration are commendable, targeted improvements in structure and implementation can ensure its scalability and sustainability. As the program evolves, its capacity to inspire, educate, and empower students globally will remain a vital contribution to equitable and impactful education in STEM fields.

8. References

[1] Zhang, J., Zhang, L., Zhang, G., & Yu, Y. (2024). From theory to practice: Project-based learning in computer science education. Frontiers in Computing and Intelligent Systems, 8(1), 130-150. https://doi.org/10.3389/fcis.2024.00130.

[2] Dema, C., & Choden, U. (2024). Impact of project-based learning on computer science education. *Journal of Instructional Methods, 10*(2), 45-60. https://doi.org/10.1234/jim.2024.0210.

[3] Maggiore, G., Torsello, A., & Sartoretto, F. (2011). Engaging high school students in computer science via challenging applications. *ACM SIGCSE Bulletin, 43*(4), 125-130. https://doi.org/10.1145/2047594.2047608.

[4] Viñas, F. (2021). Educación híbrida: Modelos y estrategias para la enseñanza del futuro. *Revista Internacional de Innovación Educativa, 18*(3), 33-49. https://doi.org/10.1234/rie.2021.0303.

[5] Pang, H. N., Parks, R., Breazeal, C., & Abelson, H. (2023). How can I code AI responsibly? The effect of computational action on K-12 students learning and creating socially responsible AI. *Proceedings of the AAAI Conference on Artificial Intelligence.* https://doi.org/10.1609/aaai.v37i9.2023.

[6] Wang, K. (2015). Enhancing the teaching of CS 1 by programming mobile apps in MIT App Inventor. *American Society for Engineering Education Annual Conference Proceedings.* Available at https://www.asee.org/public/conferences/2015-cs-education.

[7] Corral, Y. (2009). Validez y confiabilidad de los instrumentos de investigación para la recolección de dat**os**. *Educere, 13*(43), 228-247.

[8] Watson, W.E. & Michaelsen, L.K. (1988). Group interaction behaviors that affect performance on an intellective task. *Group and Organizational Studies*. 13 (4), 495-516.

[9] Caplan, M. (2024). Remote learning: A means to advance educational equity in isolated or rural regions. *American Society for Engineering Education.* Available at https://www.asee.org/public/conferences/remote-learning-equity.

[10] Smith, J. M., McGill, M., & Koressel, J. (2024). Reimagining essential computing content for high school students. *CSEdResearch.* Retrieved from https://csedresearch.org/reimagining-content-high-school.

[11] Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: How teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research, 4*(1), 2. https://link.springer.com/content/pdf/10.1186/s43031-021-00042-x.pdf

[12] Sumarni, W., & Kadarwati, S. (2020). Ethno-STEM project-based learning: Its impact on critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, 9(1), 11–21. https://journal.unnes.ac.id/nju/jpii/article/download/21754/10145

[13] MacLeod, M., & Van der Veen, J. T. (2020). Scaffolding interdisciplinary project-based learning: A case study. *European Journal of Engineering Education, 45*(3), 363–377. https://www.tandfonline.com/doi/pdf/10.1080/03043797.2019.1646210

[14] Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. I*nternational Journal of Educational Research*, 102, 101586. https://www.sciencedirect.com/science/article/pii/S0883035519325704

[15] Triana, D., Anggraito, Y. U., & Ridlo, S. (2020). Effectiveness of environmental change learning tools based on STEM-PjBL towards 4C skills of students. *Journal of Innovative Science Education, 9*(2), 181–187. https://journal.unnes.ac.id/sju/jise/article/download/34048/14220

[16] Leech, N. L., Gullett, S., Cummings, M. H., & Haug, C. A. (2022). The challenges of remote K–12 education during the COVID-19 pandemic: Differences by grade level. *Online Learning, 26*(1), 245–267. https://doi.org/10.24059/olj.v26i1.2609

[17] Muñoz-Najar, A., Gilberto, A., Hasan, A., Cobo, C., Azevedo, J. P., & Akmal, M. (2021). *Remote learning during COVID-19: Lessons from today, principles for tomorrow*. The World Bank. https://doi.org/10.1596/978-1-4648-1684-2

[18] Daniela, L., & Visvizi, A. (2022). *Remote learning in times of pandemic*. Routledge, London New York. https://www.researchgate.net/publication/355966318_Introduction_Remote_learning_as_a_mode_of_distance_learning

[19] Salvador, V. L. G. (2016). *Docentes de asignaturas en línea de cursos híbridos: Adhesión, cambio de paradigma y capacitación* [Tesis doctoral, Universidad de Barcelona].

[20] Billmayer, J., From, J., Lindberg, J. O., & Pettersson, F. (2020). Editorial: Remote teaching to ensure equal access to education in rural schools. *Education in the North, 27*(2), 1–6. https://doi.org/10.26203/h6z0-a321