Experimental analysis to assess the effectiveness of team-based blended learning in teaching computational thinking

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Abstract. *The study compared blended learning with technological support to traditional face-to-face teaching in the learning of science, culture, and computational thinking. The null hypothesis suggested that there would be no performance difference between groups G_A and G_B, while the alternative hypothesis proposed an advantage for blended learning. However, the statistical analysis found no significant differences in the performance means of the groups ($\bar{x}_{G_A} = 7.73$, $\bar{x}_{G_B} = 8.46$), indicating equivalence in teaching methods. The results suggest that both methods are equally effective in promoting learning. The study highlights the importance of rigorous assessments in understanding the impact of blended learning on student learning.*

Resumo. *O estudo comparou o ensino híbrido com suporte tecnológico ao ensino presencial tradicional na aprendizagem de ciência, cultura e pensamento computacional. A hipótese nula sugeriu que não haveria diferença de desempenho entre os grupos G_A e G_B, enquanto a hipótese alternativa propôs uma vantagem para o ensino híbrido. No entanto, a análise estatística não encontrou diferenças significativas nas médias de desempenho dos grupos ($\bar{x}_{G_A} = 7.73$, $\bar{x}_{G_B} = 8.46$), indicando equivalência nos métodos de ensino. Os resultados sugerem que ambos os métodos são igualmente eficazes para promover a aprendizagem. O estudo ressalta a importância de avaliações rigorosas na compreensão do impacto do ensino híbrido na aprendizagem dos alunos.*

1. Introduction

Education has changed over time, and even though these changes are often subtle, we cannot deny that with advances in technology, it becomes increasingly necessary to modernize teaching models to meet the demands of new generations. After all, since the beginning, technological tools have been an integral part of the teaching and learning process. When we mention technology, many people imagine cell phones, tablets and computers, however, since ancient times, human beings have always sought mechanisms and methods that would guarantee their survival [de Oliveira and Cavalcante 2016].

In all historical periods, human beings have created and recreated resources to improve their lives, and these resources we call technologies. In this sense, we understand technology as the set of methods, techniques, processes or procedures used in human activity, which are not limited to just the use of tools such as computers, cell phones, tablets, among others. According to [Fetter et al. 2019], philosopher Demerval Bruzzi states that since the beginning, schools have always used some form of technological tool, highlighting that education has always been surrounded by technologies, at least since 1650, with the use, for example, from Horn-Book technology, which consisted of a wooden board with printed letters and was used at the time to teach children to read and write religious texts [Moreira and Lima 2023b].

Therefore, the use of technologies within schools has been common since ancient times, and it is up to educator to use new technologies to their advantage, instructing students in their use within the school context. After all, the use of digital technologies has proven to be very efficient in engaging students in various school content [Ferreira et al. 2021]. In 2022, the National Common Curricular Base (BNCC) received a compliment on the use of computing, addressing three axes: Computational Thinking, Digital World and Digital Culture, within all schools and educational systems in the national territory, whether public or private, of Basic Education. BNCC established competencies and skills to be developed by students at each stage of teaching.

In this work, our objective is to explore the use of digital technologies to implement blended learning in a state public school. Specifically, we will conduct an experimental study on the development of students' computational thinking through games, based on the hypothesis that "The use of team-based Blended Learning in basic education can significantly contribute to the effectiveness of students' computational thinking". This hypothesis arose from the results of our precursor research [Moreira and Lima 2023a], in which we identified five blended learning modalities through a taxonomy. In this article, we will present the results of an experiment carried out in a public school, in the class of a basic education teacher in the pedagogical area, using the team-based Blended Learning modality, with a focus on computational thinking, and we will compare with activities carried out traditionally, without the use or with little use of digital technologies in the classroom.

2. Theoretical foundation

In this theoretical foundation section we will present the definitions related to the topic in question, to clarify the concepts and foundations necessary for understanding the subject.

2.1. Blended Learning

Blended Learning (BL), in its original definition, is a teaching modality in which online and in-person classes complement each other, with a focus on personalizing teaching, taking advantage of various digital technological resources, enabling the student to learn in your own time and at your own pace [Bacich et al. 2015]. In this teaching modality, the student is seen as the protagonist and the teacher is the mediator within this process, enabling both collective and individual activities, however this does not mean that the teacher has to create a script for each student. But, yes, he will develop different activities, to meet different profiles with more similar needs [Moreira and Lima 2023b].

Based on a Systematic Literature Review (SRL) carried out in the precursor work [Moreira and Lima 2023a], we identified five blended learning modalities, as shown in Table 1. After a detailed reading, we grouped the works presented in SRL based on similarity. Through these similarities, we seek to group more similar works into the same group and different works into other groups. This approach resulted in the categorization of works into five distinct classes (taxonomy) of blended learning, each representing a specific type. Thus, according to the work of [Moreira and Lima 2023a], the five blended learning classes are described as: Integrated Blended Learning, Connected Blended Learning, Intraschool Blended Learning, Team-based Blended Learning and Highly Tutored Blended Learning. As previously mentioned, in this work, our objective is to demonstrate the effectiveness of computational thinking in students, mediated by Team-based Blended Learning.

Table 1. Summary of blended learning concepts presented in the taxonomy in the work of [Moreira and Lima 2023a].

Autores	Definição
Integrated Blended Learning (InterBL)	
[Yang and Ogata 2022] [Phelps and Moro 2022] [Chen 2022] [Wong 2022] [Chua and Islam 2021] [Ahlin 2020] [Sarıtepeci and Çakır 2015] [Etom et al. 2021] [Darmawan et al. 2021]	Blended learning combines face-to-face and online communication, incorporating different technological resource technologies into the structure of classes, allowing students to explore topics and share experiences in person and online.
Connected Blended Learning (ConBL)	
[Argyriou et al. 2022] [Ahmed et al. 2022] [Avramenko et al. 2021] [Gede Sudirtha et al. 2022] [Abdul Rahim et al. 2022] [Fola-Adebayo 2019]	Blended learning is a combination of synchronous and asynchronous activities, which can occur through in-person and virtual learning through platforms or in fully online formats.
Intraschool Blended Learning (IntScBL)	
[Adams et al. 2020] [de Brito Lima et al. 2022] [Kundu et al. 2021] [Indriyanti et al. 2020]	Blended learning combines classroom activities with computer-based learning, both online and offline.
Team-based Blended Learning (TBasBL)	
[Shen et al. 2022]	Blended learning consists of activities that can be carried out online, in a group or individually.
Highly Tutored Blended Learning (HTutBL)	
[Cui et al. 2022]	Blended learning combines learning environments, with the use of digital platforms and support from teachers in all environments.

Source: Prepared by the authors.

2.2. Gamification

Gamification is one of the active methodologies that has gained prominence in recent years [Sendacz et al. 2022]. Using game elements and mechanisms in educational contexts, transforms learning into a more engaging and dynamic experience. Gamification brings the possibility of working on activities in a playful way using technological resources within the school environment. According to [Lima et al. 2017], gamification consists of a way of taking games with educational purposes, in which the student learns the content to be taught. For [da Silva and Lima 2020], educational games are tools that encourage students to learn with playful resources, aiming to complement their academic training in a fun and enjoyable way [Pires et al. 2020]. Gamification can be applied to different areas of knowledge [Passos et al. 2021, Queiros et al. 2022] and educational levels [de Moraes et al. 2022], providing an innovative and effective approach to learning.

2.3. Computational thinking

Computational thinking can be defined as a fundamental mental skill that involves solving problems logically and systematically, using concepts and techniques from computer science [Kaminski et al. 2021, de Mattos Vogel and Pereira 2023]. Introducing computational thinking to elementary school students is extremely important [Kretzer et al. 2020], as it prepares them to face the challenges of the constantly evolving digital world. By developing computational thinking skills, students become better able to analyze complex problems, breaking them down into smaller parts and applying algorithms to find effective solutions. Furthermore, creating games, whether offline or online [da Cruz et al. 2021], is an excellent way to introduce these techniques to students. When developing a game, students are encouraged to think algorithmically, plan and sequence actions, identify patterns, and test solutions [Gonçalves et al. 2022]. This not only helps them understand the fundamentals of computer science, but also improves their problem-solving, creativity, and critical thinking skills [Dutra et al. 2023, Lima et al. 2021].

3. Materials and methods

This work is classified as quasi-experimental research, characterized by sharing similarities with experimental research, but differing in the way the variables are controlled. While in experimental research the variables are strictly controlled by the researcher, in our comparative study, some variables could not be manipulated with such precision [Severino 2017]. This is because, when manipulating an independent variable to observe its effect on a dependent variable, it is not always possible to control all the other variables that can influence the result. This limitation is common in educational environments, where several external factors can affect the study. For example, in this paper, when comparing student performance, it is not possible to control for other factors such as family environment or individual motivation.

Therefore, our objective was to compare two groups to evaluate the effects of an intervention, in this case, the effectiveness of computational thinking in the development of a game, through the implementation of Team-based Blended Learning, one of the five classes derived from taxonomy [Moreira and Lima 2023a]. In the aforementioned hypothesis, the independent variable is the type of teaching used: team-based blended learning. The dependent variable is the effectiveness of students' computational thinking in developing a game.

The study was conducted in a city with a population of just over 700 thousand inhabitants, located in the southeast region of Brazil, in a small state school, attended by around 540 students. In this research, we worked with four classes of 9th-grade students in the final years of elementary school in Basic Education. For a better understanding of the activities described, we divided the four rooms into two groups, which we call Group A (G_A) and Group B (G_B), composed, respectively, of 61 and 42 students.

Each group received a different teaching modality during the activities carried out over four weeks. When dividing the groups for the study, the manipulation of the independent variable consisted of exposing students to different teaching methods: in G_A, we opted for the conventional approach, conducting all game construction activities in the school environment, using a whiteboard, brush, handouts and expository classes. For G_B, we chose the BL modality, incorporating the development of a game to stimulate computational thinking, considering team-based blended learning, based on one of the conceptual frameworks presented in the work of [Moreira and Lima 2023a]. In this last group, using BL, face-to-face activities took place in the school environment, plus activities carried out in groups of four to five students online. The dependent variable, in this case, will be assessed by measuring the effectiveness of students' computational thinking in each group.

At the end of the activities, both groups were evaluated procedurally and responded to a self-evaluation questionnaire. We adopted two statistical approaches to analyze the results obtained with the questionnaire and the procedural evaluation of students during the construction of the games. First, we conducted a comparative descriptive analysis of the Likert type between the groups G_A and G_B. We then analyzed hypothesis testing. To analyze Likert-type data, we used R Studio, a free platform that allows even people with minimal programming knowledge to use the R language. The application's simple and organized interface makes it easy to use the tools. We used the "Two-Sample t Test Calculator" available on the Stats website to analyze the hypothesis test.Blue[1], which offers simple, easy-to-use and completely free online statistical software.

4. Experience report and quasi-experiment

In this section, we will present an experience report on the application of quasi-experiments in four classes of the 9th year of elementary school, final years, of basic education, in a public school in the state network of Minas Gerais. The teacher responsible for applying quasi-experimental research sought to use the various technologies available to make classes more attractive, aiming to improve student engagement in the proposed activities, such as building games, and facilitating the acquisition of new knowledge, in particular, computational thinking.

In the first class, groups G_A and G_B had an exhibition on the theme of the life project: science, culture and art, through slides. The main objective was to encourage students to reflect on the importance of planning the future by their personal and social objectives, so that they can make conscious choices. In this context, it is essential to consider which principles and values will be followed throughout each person's journey, and how activities such as science, culture and art can positively impact people's lives. After the explanation of the concepts of life project, the story of William Kamkwamba was presented[2], who, at the age of 14, frequented his village library after being forced to interrupt his studies. Through his readings, Kamkwamba was able to build a windmill with materials found in a scrapyard, capable of generating electricity and driving a water pump, transforming the lives of all the inhabitants of his community.

In the second class, students from Group G_A received the task of carrying out research on the biography of a significant personality for them. This personality could be a famous artist, scientist, writer, religious leader, inventor, athlete, among others. In groups of up to five students, it was suggested that they create a mini poster the size of an A4 sheet containing the biography of these personalities and present it to the class in the next class. Each group had five minutes to present. The students in Group G_B, like those in Group G_A, were tasked with researching the biography of someone they wanted to know better. As an activity, they should produce a video, no longer than 5 minutes, and send it to the teacher via Google Classroom, email or WhatsApp, to be presented to the whole class in the next class.

In the third class, students from Group G_A were challenged to create a game based on the theme "Life Project". They needed to define the type of game, the number of participants, the objective and the rules, aiming to promote computational thinking. The activity was carried out unplugged in teams of four to six participants, with materials such as bond sheets, cardboard, colored paper, glue, scissors and brushes available. The

[1]Stats.Blue Calculator, Method Two-Sample t Test Calculator, Access link: `https://stats.blue/Stats_Suite/two_sample_t_test.html`.

[2]The Boy Who Harnessed the Wind (2019), is a British film, in the biographical drama genre, written, directed and starring Chiwetel Ejiofor, with a script based on the memoir The Boy Who Harnessed The Wind, by William Kamkwamba and Bryan Mealer.

students had 50 minutes to produce the game. For Grupo G_B, the proposal was to create an online game based on the biography of the researched personality. In class, two free online games, Flippity and Kahoot, were presented through projection to demonstrate the interface and creation possibilities. Students were advised that these were just suggestions and that they could choose any other free digital tool for the activity. Two YouTube videos on how to create games using Flippity and Kahoot have been made available on Google Classroom. Students should create the game in groups and send the game link via email or WhatsApp up to one day before the next class, so that the teacher could play and evaluate them. It was established that each team, from both G_A and G_B, would have five minutes in the following class to present the game to the teacher.

In the fourth and final class, students began by answering a questionnaire based on the Likert scale to assess their level of effort and learning during the development of the activities, as well as their perception of the teacher's skills and receptivity throughout the process. In addition, they evaluated and gave a grade for the activities carried out over the four weeks. Students had five minutes to complete the self-assessment. After this stage, the groups had the opportunity to present their games to the teacher and classmates. In the G_A Group, games such as Treasure Hunt, Memory Game, Quiz, Track Game and Game Similar to Chess were developed and presented. In the G_B Group, the games developed and presented included Treasure Hunt, Memory Game, Quiz, Trail Game and 7 Errors Game. To do this, students used platforms such as Flippity, Kahoot, Canva and Quizclass.

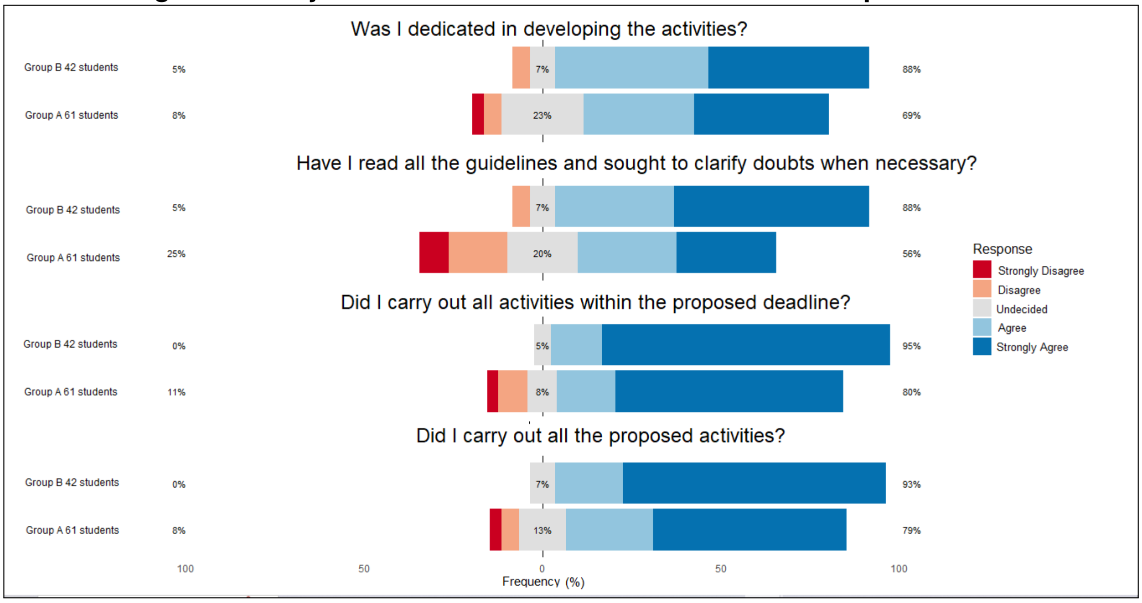
5. Analysis and Discussion of Results

Our goal was to analyze whether the BL activities resulted in better learning and greater engagement from the students. To conduct a comprehensive analysis, we assigned 10 points to the activities carried out over the four weeks for each group. We used the following evaluation criteria: participation in activities, creativity, theoretical foundation, teamwork, communication, level of difficulty of the games created (computational thinking), clarity of the game objectives, and dedication to completing the activities. In addition to assigning grades, we applied an evaluation based on the Likert scale to assess the level of effort and learning of each student, the skills and responsiveness of the teacher during the activities, and the overall assessment of the activities carried out over the four weeks.

For a better understanding, we will analyze the evaluations by parts. Firstly, we will direct our focus to the self-assessment carried out by students after completing the activities proposed for groups G_A and G_B. Regarding questions related to the level of effort in developing activities, let's see Figure 1. When analyzing Figure 1, we can notice that G_B demonstrated greater effort in developing activities compared to G_A. For example, regarding the question "I read all the guidelines and sought to clarify doubts when necessary", while 88% of G_B responded Completely Agree or Agree, only 56% of G_A responded Completely Agree or Agree and 25% responded Disagree or Disagree, that is, a quarter of G_A students stated that they had not read or sought to clarify doubts when necessary.

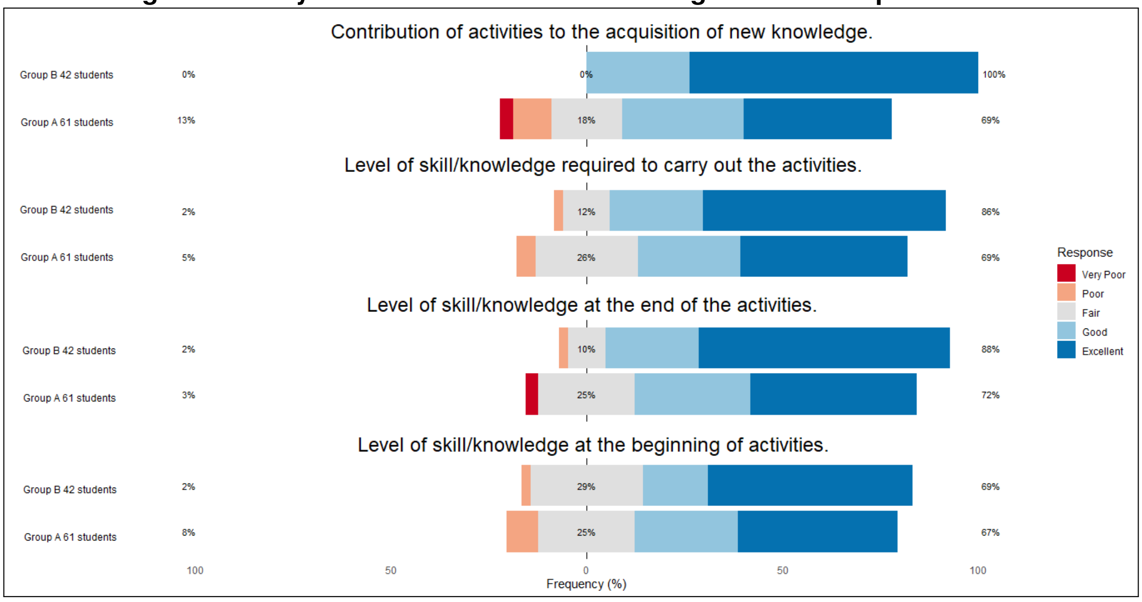
When we look at the questions related to the student's level of learning as shown in Figure 2, we can see that 100% of G_B students declared that the activities contributed to the acquisition of new knowledge, in return for G_A 13% of students disagreed that the activities developed contributed to the acquisition of new knowledge. When analyzing the questions related to the level of knowledge required to carry out the activities and the level of knowledge at the end of the activities, G_B once again evaluated positively about

Figure 1. Analytical Likert Chart of Level of Effort for Groups A and B.



Source: Prepared by the authors.

Figure 2. Analytical Likert chart of the learning level of Groups A and B.



Source: Prepared by the authors.

G_A, with a difference of approximately 15%. Regarding the level of knowledge at the beginning of the activities, we can note that in both groups the answers were very close, demonstrating a satisfactory level of prior knowledge before carrying out the activities.

In our last question, we asked students to make a general assessment of how the activities developed over the four weeks. As we can see in Table 2, none of the groups considered the activities to be of a “Weak” level. In G_A, one student evaluated it as ”Moderate” and seven as “Satisfactory”. At the “Very Good” level, 32.3% in G_A and 12.2% in G_B. At the ”Excellent” level, approximately 55% in G_A and 88% in G_B. This leads us to conclude that, for students, the activities carried out through team-based blended learning

Table 2. Table of analysis of the final evaluation of the activities developed

QUESTION	Group A 61 students ($N = 61$)	Group B 42 students ($N = 42$)	Total ($N = 103$)
What is your final evaluation of the activities developed?			
Poor	0 (0%)	0 (0%)	0 (0%)
Moderate	1 (1.6%)	0 (0%)	1 (1.0%)
Satisfactory	7 (11.5%)	0 (0%)	7 (6.8%)
Very Good	19 (31.1%)	5 (12.2%)	25 (24.3%)
Excellent	34 (55.7%)	37 (88.1%)	71 (68.9%)
Groups Sizes			
Group A 61 students	61 (100%)	0 (0%)	61 (60.2%)
Group B 42 students	0 (0%)	42 (100%)	42 (39.8%)
Self-assessment Averages	4.4098	4.881	4.6019

Source: Developed by the authors.

presented satisfactory results, according to Likert-type self-assessments.

Continuing the analysis, starting from the question that guides this study: "Can the use of Blended Learning in Elementary Education in the public school system contribute to efficient learning for students?" The hypothesis raised is that students subjected to team-based blended learning, with gamified activities to stimulate computational thinking, demonstrate significantly higher academic performance when compared to conventional teaching, with little or no use of digital technologies. For this analysis, we opted for hypothesis testing, specifically the Student's t-test, widely used in statistics to determine if there is a significant difference between the means of two groups from a population, paired samples, or independent samples with some characteristic to be analyzed [Lopes et al. 2015].

At the beginning of the analysis, we did not have enough evidence to conclude. Thus, our null hypothesis (H_0) posits that there is no significant difference in the performance of students between the group that received team-based blended learning with technology support to stimulate culture, science, and computational thinking, and the group that received traditional face-to-face teaching without technological elements for the same stimulus. On the other hand, the alternative hypothesis (H_1) suggests that there is a significant difference in the performance of students between the group that received team-based blended learning with technological support to stimulate culture, science, and computational thinking, and the group that received traditional face-to-face teaching without technological elements for the same stimulus.

In this context, the null hypothesis (H_0) assumes that any difference observed in student performance is due to chance, not influenced by the introduction of blended learning with technological support to teach science, culture, and computational thinking. The alternative hypothesis (H_1), on the other hand, suggests that the introduction of blended learning, especially with technological elements to teach science, culture, and computational thinking, will result in a significant difference in student performance compared to traditional face-to-face teaching.

For this study, we will analyze two independent samples, in this sense, we will use the means (μ) and also the population standard deviations. If the significance level (α) is greater than 0.05, the null hypothesis (H_0) would not be rejected, and if it is less than

0.05, H_0 would be rejected. Thus, the objective was to compare the population means μ_1 and μ_2, with H_0: $\mu_1 = \mu_2$ and H_1: $\mu_1 \neq \mu_2$. For this analysis, we used some criteria and their respective weights, as we can see in Table 3, which represents the criteria for

Table 3. Performance evaluation process and group averages

Criterion used by the teacher to evaluate the students' teams	Group A	Group B
Creativity	2.0	2.0
Theoretical foundation	2.0	2.0
Game difficulty level	2.0	2.0
Clarity in-game objective	2.0	2.0
Participation	1.0	1.0
Teamwork	1.0	1.0
Total	10.0	10.0
Group averages	**7.72951**	**8.46429**
Standard deviation	**1.72140**	**0.66620**
Student's t-test	0.1385	
p-value	0.8917	

Source: Compiled by the authors.

evaluating academic performance, along with the means obtained by groups G_A and G_B.

When analyzing the arithmetic mean of the grades achieved by the students in both groups, we observe that Group B (G_B) obtained a higher average compared to Group A (G_A). This initially leads us to suppose that Group B received a more effective method for learning than Group A. Now, let's examine the results obtained from the statistical calculation of the Two-Sample t Test.

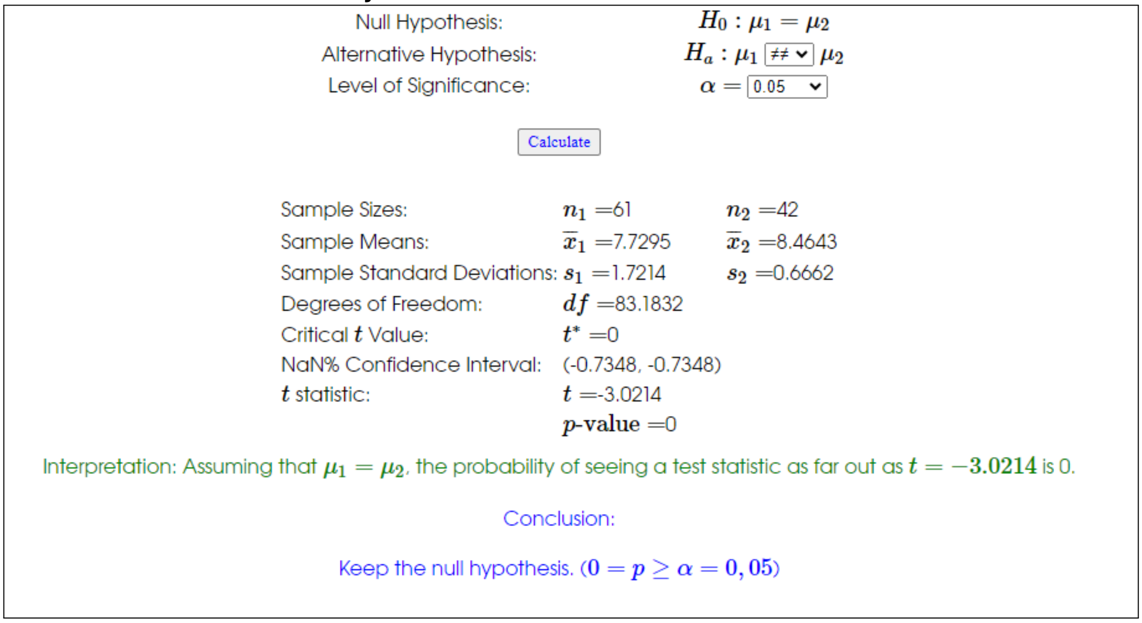
The significance level analysis shows that the difference between the two means is not statistically significant; therefore, the null hypothesis should be retained. In this sense, it can be concluded that there are no significant differences between the two means, as seen in Table 3. Thus, there is no significant difference between groups G_A (traditional in-person team-based teaching without technology mediation) and G_B (blended team-based teaching mediated by technology), as evident in Figure 3. This implies that traditional in-person teaching in group G_A and blended learning are equivalent in teaching science, culture, and computational thinking to students.

Although the evaluation results confirm the initial hypothesis, it is important to highlight some limitations of this research. The data obtained are part of the experience report provided by the teacher responsible for the classes. For a more comprehensive analysis, it would be necessary to expand the study to include students from more grades of basic education, covering a wider age range. Additionally, students would need to be exposed to various types of blended learning, which would require a longer period of study and research to obtain more significant data. Another limitation is that students were evaluated by only one teacher. For a more comprehensive analysis, it would be interesting for students to be assessed by two or more teachers.

6. Final considerations

Team-based blended learning is essential for teaching science, culture, and computational thinking in Basic Education, as it promotes collaboration among students, encouraging

Figure 3. Illustration depicting the graphical representation and interpretation of the Student's t-test analysis.



Source: Prepared by the authors.

teamwork and knowledge exchange. Additionally, the use of educational technologies in blended learning provides more dynamic and interactive learning experiences, preparing students for the challenges of the 21st century. Through the assessments conducted over the four weeks, it was possible to analyze the contribution of BL applied in the final years of elementary school. Although the experience report was conducted over just four weeks, with one class per week, it provided insight into the potential benefits of this type of learning for students' lives.

Some limitations of this report include the small number of participants, sampling conducted only with students from the same grade level, imbalance in the number of participants between the two samples, and analysis limited to just one subject. For future studies, it is necessary to conduct broader research, with a longer application period of the method and the types of BL described in Table 1 of this article, to achieve greater statistical robustness and the possibility of generalizing the results.

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