

Educational Robotics and Student Engagement in the Mathematics Learning Process

Thaymara Cristina de Souza Romulo

Universidade Federal de Viçosa

Viçosa, MG — Brasil

✉ thaymara.romulo@ufv.br

ORCID [0009-0002-2952-3473](https://orcid.org/0009-0002-2952-3473)

Rejane Waiandt Schuwartz de Carvalho Faria

Universidade Federal de Viçosa

Viçosa, MG — Brasil

✉ rejane.faria@ufv.br

ORCID [0000-0002-2422-969X](https://orcid.org/0000-0002-2422-969X)

Alexandre Santos Brandão

Universidade Federal de Viçosa

Viçosa, MG — Brasil

✉ alexandre.brandao@ufv.br

ORCID [0000-0001-5990-2218](https://orcid.org/0000-0001-5990-2218)



2238-0345 

10.37001/ripem.v16i2.4657 

Received • 25/06/2025

Approved • 17/05/2026

Published • 28/08/2026

Editorial • Edvonete Souza de Alencar 

Veridiana Rezende 

Abstract: This article aims to investigate the role of Educational Robotics in the mathematics learning process of students in the final years of elementary school. The methodological approach is qualitative in nature, and the data were collected at State School Raul de Leoni, a public school. The research subjects were students from a seventh-grade class. Data were gathered through field notes, photographs, videos, activity sheets, and a discussion circle. Data triangulation was conducted based on the four stages of Mathematical Investigations and the four key elements in the organization of Computational Thinking development. The analysis allowed us to infer that it is possible to establish connections between Robotics and Mathematical Investigations. We conclude that Robotics presents itself as a powerful tool for engaging students in the construction of knowledge, as the students demonstrated interest and active involvement in Robotics activities.

Keywords: Mathematics Education. Digital Technologies. Computational Thinking. Mathematical Investigations. Upper Elementary School.

Robótica Educativa y el Compromiso de los Estudiantes en el Proceso Formativo en Matemáticas

Resumen: Este artículo tiene como objetivo investigar el papel de la Robótica Educativa en el proceso formativo en Matemáticas de estudiantes de los últimos años de la Educación Primaria. La propuesta metodológica es de carácter cualitativo y los datos fueron producidos en la Escuela Estatal Raul de Leoni. Los sujetos de la investigación fueron estudiantes de un grupo de séptimo grado. Los datos fueron analizados a partir de anotaciones en el cuaderno de campo, fotografías, videos, hojas de actividades y una rueda de conversación. La triangulación de los datos se realizó a la luz de los cuatro momentos de las Investigaciones Matemáticas y de los cuatro principales elementos de la organización del desarrollo del Pensamiento Computacional. El análisis de los datos permitió inferir que es posible establecer relaciones entre la Robótica y las Investigaciones Matemáticas. Concluimos que la Robótica se presenta como una herramienta con potencial para involucrar a los estudiantes en la construcción del conocimiento, ya que los alumnos se mostraron interesados y comprometidos con las prácticas desarrolladas con la Robótica.

Palabras clave: Educación Matemática. Tecnologías Digitales. Pensamiento Computacional. Investigaciones Matemáticas. Últimos Años de la Educación Primaria.

Robótica Educacional e o Engajamento dos Alunos no Processo Formativo em Matemática

Resumo: Este artigo objetiva investigar a atuação da Robótica Educacional no processo formativo em Matemática de alunos dos Anos Finais do Ensino Fundamental. A proposta metodológica é de cunho qualitativo e os dados foram produzidos na Escola Estadual Raul de Leoni. Os sujeitos da pesquisa foram estudantes de uma turma do sétimo ano. Os dados foram analisados a partir das anotações no caderno de campo, fotografias, vídeos, folhas de atividades e uma roda de conversa. A triangulação dos dados foi realizada à luz dos quatro momentos das Investigações Matemáticas e nos quatro principais elementos da organização do desenvolvimento do Pensamento Computacional. A análise dos dados possibilitou inferir que é possível estabelecer relações entre a Robótica e as Investigações Matemáticas. Concluímos que a Robótica se apresenta como uma ferramenta com potencial para engajar os alunos na construção do conhecimento, afinal, os estudantes se mostraram interessados e envolvidos nas práticas com a Robótica.

Palavras-chave: Educação Matemática. Tecnologias Digitais. Pensamento Computacional. Investigações Matemáticas. Anos Finais do Ensino Fundamental.

1 Educational Robotics in the training process

Technology is associated with the set of knowledge and practices applied to perform specific tasks. It is understood as a technique that transcends the mere use of machines since it encompasses the knowledge embedded in human practices over time (Santos, Santos & Javaroni, 2023; Vieira-Pinto, 2005). Vieira-Pinto (2005) criticizes the idea of technological explosion, explaining that this complex concept is intertwined with human development and the pursuit of improvements, thus being a discussion that is updated as society develops.

According to Lévy (2010), technologies are actors. The understanding of how technologies act occurs because knowledge does not happen in isolation; after all, according to the author, thinking is individual, but intelligence is collective. In this sense, the technologies of intelligence, namely orality, writing, and information technology, are the main representatives that shape our thoughts and attitudes. Therefore, technology consists of a broad concept linked to social and cultural evolution (Santos *et al.*, 2023).

In particular, digital technologies constitute a comprehensive set of tools, systems, and resources that, based on hardware, software, and symbolic data, develop various electronic devices starting with computers and expanding to mobile devices, multiple communication networks, and online services (Costa, 2009).

In the educational sphere, digital technologies can contribute significantly to the teaching and learning processes (Oliveira & Macêdo, 2025). However, we need to keep in mind that technologies do not determine results, but condition them (Lévy, 2010) through planning linked to educational practices. In other words, "to blame technology for its 'negative social impacts', or even its 'positive social impacts', is to ignore, first of all, how much — objectively and subjectively — it is constructed by social actors, that is, in the context of society itself" (Benakouche, 1999, p. 2).

Thus, thinking about Robotics in Education, as well as any other digital technologies, requires practices aligned with the curriculum and school content to promote meaningful learning for students. The class teacher, in turn, plays a fundamental role that goes beyond

planning such practices: that of a knowledge mediator, being active and responsible for fostering a critical and reflective view of Robotics without overvaluing or devaluing its presence in the school environment.

Regarding Educational Robotics, Azevedo (2022) points out that linking it to the student's educational process stimulates the development of cognitive skills essential for learning Mathematics. In general, Educational Robotics provides a conducive environment to work in an interdisciplinary or transdisciplinary way, establishing relationships between two or more school subjects as it mobilizes teaching as a research strategy that crosses school boundaries and establishes connections with students' daily lives (Azevedo, 2022; Pereira *et al.*, 2023).

In the formative process, especially in Mathematics, the construction of learning occurs through communication between the concrete and the abstract, in which the processes of Educational Robotics are essential. Among these processes is the application of mathematical (or other) concepts and terms to practice, problem-solving, as well as reviewing the results with the aim of analyzing them. These processes drive teacher-student-robot interaction, allowing the growing development of multiple skills, so that, “[...] by doing science and developing technologies, the student can perceive themselves as an agent of trans(formation) in society” (Azevedo, Maltempi & Powell, 2022, p. 236).

Although it is a current topic, it is not new. Papert, one of the pioneers in the field, was already conducting work discussing the subject in 1960 in light of constructionism when he developed the first prototype of a robot turtle in 1980 (Campos, 2019; Gadanidis, Javaroni, Santos & Silva, 2022). These studies showed that Robotics can assist in teaching and learning processes, developing different essential practical skills. For Papert (2008), digital technologies can boost teaching because if a child learns Mathematics in an experimental and intuitive way through observation, they can also learn to use the computer through play.

The constructionist approach advocates learning by doing. From this perspective, children learn when they are actively engaged in building something meaningful (Campos, 2019). This form of learning, in which children are encouraged to experiment, discover, and construct, can provide the building of solid knowledge that does not fade over time. In this way, learning can become meaningful and adapted to the individual needs of students, a possibility that invites us to reflect on the use of computing and the encouragement of Computational Thinking (CT) to spark students' interest in Mathematics (Papert, 1980).

Incorporating the PC in the Educational scope becomes an alternative to contribute to a quality Education with contextualized teaching, permeated by situations and investigative activities arising from real problems in which students can develop skills related to Mathematics and programming simultaneously (Ashtiani & Demarchi, 2025, Gadanidis *et al.*, 2022; Papert, 1980). Likewise, Mathematical Investigations, both in the context of research and in the school setting, have prompted advances in educational practices that address the current political, economic, and environmental frameworks, seeking to make the classroom an environment where knowledge is constructed through exchange, valuing the students' prior knowledge as well as dialogue (Corradi, 2011).

Given the relevance of this study for the educational scenario, as well as the aforementioned conceptions, this article¹ aims to investigate the role of Educational Robotics

¹ We clarify that this article is part of a master's thesis defended in the Postgraduate Program in Education at the Federal University of Viçosa, organized in multipaper format, written by the first author, supervised by the second author, and co-supervised by the third author (Romulo, 2025).

in the formative process of Mathematics for students in the Final Years of Elementary School. In this context, we seek to answer the following guiding question: How can the integrated work between Computational Thinking, Mathematical Investigations, and Robotics in Education contribute to students' engagement, autonomy, and development of critical thinking, especially in the process of creating and analyzing algorithms? Subsequently, we delve into Computational Thinking and its range of possibilities in the educational scenario.

2 Computational Thinking

Computational Thinking (CT) consists of an important process that can be explored from Early Childhood Education, evolving together with the stages of schooling up to Higher Education. Exploring CT provides the student with a critical view regarding the technological world (Ashtiani & Demarchi, 2025; Campos, 2019; Gadanidis *et al.*, 2022). In other words

It is not enough to just know how to use the computer or software such as text and productivity editors. Technologies such as 3D printing, virtual and augmented reality glasses, robotics, artificial intelligence, and video games are already part of everyday life and require this generation to have the ability to understand how these technologies work for contextualized application. (Martins & Oliveira, 2023, p. 34)

The ability to navigate the internet or copy and paste data is not a skill related to the CT. It would be necessary that, when performing these or any other actions involving digital technologies, the student had a critical stance (Blikstein, 2008). In this sense, Wing (2006) argues that the CT should not be restricted to scientists, since it enables the combination of computer capabilities with human skills, understanding their behavior, allowing to think about the best way to solve a problem, designing systems, and performing tasks that, without the aid of digital technologies, we would not be capable of.

In a reflection on CT, Azevedo (2022) presents four main elements for solving problems according to the organization of the development of this type of thinking, namely: decomposition, pattern recognition, abstraction, and algorithm. This set of elements can be used to solve simple or complex problems, being possible to identify them throughout the entire action.

Regarding the decomposition element, in Computer Thinking we reformulate an apparently difficult problem into one or several problems that we know how to solve, whether through reduction, incorporation, transformation, or even simulation (Wing, 2006). This strategy is called decomposition, that is, the fragmentation of a problem considered complex and represents the process of analyzing and interpreting a problem or task by breaking it down into specific data such as subproblems or subtasks with the aim of finding the solution for the whole (Navarro & Sousa, 2023).

On the other hand, pattern recognition contributes significantly to the identification of processes that repeat logically and orderly, facilitating the prediction of future occurrences and the optimization of solutions, enhancing the understanding of relationships between different elements and allowing for better comprehension and analysis of data (Azevedo, 2022). Complementing this idea, Navarro and Sousa (2023) state that recognizing a pattern denotes a movement of identifying repetitions and similarities in a problem or task that deals with the identification of analogies in different processes.

Abstraction, in turn, according to Wing (2011), is directly related to CT, as it requires an active, critical, and creative stance when analyzing a problem, differing from merely solving

tasks. However, understanding abstract content has been a recurrent challenge among students. This happens because abstraction requires thinking about knowledge already built through recurring reflection. It is necessary to find ways to reorganize ideas and construct new knowledge. Understanding that students are capable of making progress through active learning that allows them to explore situations, observe results, and build their own conclusions is relevant to CT (Azevedo, 2022).

Finally, the algorithm plays the important role of bringing together the other foundations of Computational Thinking — decomposition, abstraction, and pattern recognition — into something executable, allowing various problems to be solved in the short term, whether they are interpreted and executed by humans or by machines. However, Azevedo (2022) warns that the word algorithm may evoke a mistaken idea of a complex concept, but we can define it as a "set of steps that make up a replicable solution" (Guiraze, Singo & Chin, 2023, p. 6). Azevedo (2022, p. 44) adds that "it can be understood as a set of logical-procedural and analytical rules." Thus, it is not just steps to be followed, but rather logical and orderly organized steps to be followed in a rigorous structure.

Complementing this idea, in the National Common Curricular Base (BNCC) it is stated that "an algorithm is a finite sequence of procedures that allows solving a given problem. Thus, the algorithm is the decomposition of a complex procedure into its simplest parts, relating them and ordering them" (Brazil, 2018, p. 271). According to the BNCC, algorithms have relevance in the formative process in Mathematics. Therefore, it is recommended that they be addressed as a subject of study in classes and that, through the development of the algorithm as a skill, the relationship with algebraic language be strengthened (Brazil, 2018).

Wing (2011) points out that the algorithm consists of a process of abstraction, one of the most important and high-level processes in computer science, which makes it possible to scale and deal with complexity, allowing the construction of increasingly larger systems. By abstracting, the student reflects on the steps, execution, inputs, and outputs of a specific algorithm, thus exercising logical reasoning and establishing relationships between the abstract and the concrete. Furthermore, "work with computer science, in the specificity of Mathematics Education, is understood as an opportunity for the student to create new things with the curricular content instead of browsing, copying, and pasting data with the computer" (Azevedo, 2022, p. 45).

Moreover, when constructing an algorithm, it is possible to "understand it and transpose it to different contexts and possibilities, relating it to academic and technical knowledge with real problems" (Azevedo, 2022, p. 46). In this way, we understand that practices, regarding designing algorithms, make it possible to reflect on their construction and execution and relate them to everyday problems in different contexts and possibilities, contributing to the development of training in Mathematics based on PC skills. Therefore, it is not about teaching that prioritizes the formalization of concepts and rules through the memorization of patterns and sequences, but rather about work that must happen meaningfully, employing ways of problematizing activities that encourage students to produce strategies (Navarro & Sousa, 2023).

We envision in the work with Robotics an alternative for the development of the CT and the student's ability to take on an active and critical stance. Thus, the CT presents itself as a possibility to forge intellectual ideas for the construction of knowledge in different areas, among which is Mathematics. Likewise, we present the Mathematical Investigations that will be considered below.

3 Mathematical Investigations

Mathematics is a human science in constant construction and improvement (D'Ambrosio, 2013). Through exploration, investigation, or simply doubt, new possibilities for the expansion of science are found, and from them, Mathematics evolves immersed in different social, economic, and cultural contexts. In a non-linear path, humanity invented numbers, wheels, constructions, computers, forms of long-distance communication, and QR codes. Every historical milestone of human development is influenced by Mathematics, which highlights the importance of Mathematical Investigations for understanding and transforming the world (Oliveira & Macêdo, 2025). With the constant search for answers, we frequently find ourselves solving problems, conjecturing, proving or discarding hypotheses, and, also, with the aim of being understood, we argue and justify ourselves whenever necessary.

According to Corradi (2011), investigations are likewise present in Mathematics Education through research and their focuses on changes in the Educational field, technological transformations, and teaching practices, and they are full of challenges and subjectivities stemming from the reality of each school. The author highlights that the practice of Mathematical Investigations contributes to the construction of learning, the strengthening of conjectures, and the implementation of changes within the Educational scope. Investigative activities, in general, stand out for involving explorations and reasoning that lead students to justify, generalize, find counterexamples, among others (Ponte, Quaresma, Mata-Pereira & Baptista, 2015).

In this context, the teacher is responsible for mediating the classes. It is necessary to be attentive so as not to structure investigative situations that are too difficult, leading to discouragement, nor too easy, causing disinterest. Similarly, one should not give too many hints to the point of influencing decisions, nor allow misunderstanding of the task due to a lack of data. It is up to the teachers to teach students that errors in investigative studies should not be discarded or treated as failures, but as an indication that it is necessary to follow a new path. By establishing a good relationship with the students, it is possible to support them in their development, paying attention to an inquisitive stance that guides the group to reflect through dialogue. This mediator must provide new information when necessary, as well as recall mathematical concepts that assist the class (Rodrigues, Ponte & Menezes, 2020; Ponte, Oliveira, Brunheira, Varandas & Ferreira, 1998). For analytical purposes,

[...] carrying out a mathematical investigation involves four main stages. The first encompasses recognizing the situation, its preliminary exploration, and the formulation of questions. The second stage refers to the process of formulating conjectures. The third includes carrying out tests and the eventual refinement of the conjectures. And finally, the last concerns the argumentation, the demonstration, and validation of the work carried out. (Ponte, Brocardo & Oliveira, 2009, p. 20)

Thus, as presented by Ponte *et al.*, (2009), the first stage consists of the discovery of the problem in which the students must recognize it and explore the problematic situation through the formulation of questions. In this way, “[...] in mathematical investigation the starting point is an open situation, that is, the question is not completely defined, leaving to the investigator (student) a fundamental role in its realization” (Ponte *et al.*, 2009, p. 9).

In the second stage, the organization of data takes place in order to formulate conjectures and statements regarding this. The Mathematical Investigation approach provides students with the opportunity to go through all stages of the process. After the introduction of the task, they engage in an investigation guided by questions, followed by discussions of the results. Next,

we move towards the systematization of the process obtained from the conclusions presented, allowing students to have a record of the various aspects explored throughout the activity, promoting a more complete understanding and documentation of the discoveries made during the Mathematical Investigation.

Already, in the third moment, it is necessary to carry out tests in order to refine the conjectures previously elaborated. At this moment, the student makes use of their prior knowledge to discover new factors that can deny or affirm the conjecture, which guide them to the next phase. Finally, it is the time to validate the conjectures and justify the conclusions based on the discoveries and to evaluate all the reasoning used or the results of such reasoning.

4 Methodology

In qualitative research, there is an effort to understand different perspectives; thus, any factor can lead to an understanding of the phenomenon being studied. Within the qualitative scope, questioning the object of study helps guide the search for aspects and peculiarities of the phenomenon in question (Bogdan & Biklen, 1994). Furthermore, care must be taken to not to misrepresent the dialogues, analyzing them responsibly, as well as exercising caution when making descriptions.

Qualitative data do not follow precise rules or previously established steps regarding data production and analysis. However, this does not mean that there should be no planning. Goldenberg (2007) recommends establishing techniques and procedures that are suitable for the context of the particular object since qualitative data cannot be standardized. The author also points out that such a task should involve the researcher's creativity, flexibility, and experience. In this way,

To carry out research, it is necessary to promote the confrontation between data, evidence, information collected about a given subject, and the theoretical knowledge built regarding it. In general, this is done based on the study of a problem, which at the same time arouses the researcher's interest and limits their research activity to a specific portion of knowledge, which they commit to building at that moment. (Lüdke & André, 2013, p. 2)

Thus, triangulation is made by relating the data found with the literature studied, with the experiments carried out and with the subjectivity of the researchers. Therefore, because we understand that an investigative environment makes the construction of mathematical knowledge meaningful, allowing the exploration of situations and the active participation of students in society from critical and creative experiences, we emphasize that this work will be based on the four moments of Mathematical Investigations (Ponte *et al.*, 2009) and the four main elements of the organization of the development of Computational Thinking (Azevedo, 2022).

In this work, we will give special focus to regular polygons, in particular, to the square and the equilateral triangle. In this study, we assume for a polygon that "given three points, A, B, and C, not collinear, the joining of segments AB, AC, and BC is called triangle ABC" (Dolce & Pompeo, 2013, p. 35). Thus, this is the definition for a polygon to be a triangle. More specifically, we define triangles as "equilateral if, and only if, they have all three sides congruent" (Dolce & Pompeo, 2013, p. 36). In turn, "a convex plane quadrilateral is a square if, and only if, it has four congruent angles and four congruent sides" (Dolce & Pompeo, 2013, p. 98). Both the equilateral triangle and the square are regular polygons, that is, a convex polygon that has all sides congruent (is equilateral) and all angles congruent (is equiangular)

(Dolce & Pompeo, 2013).

The choice of these polygons is justified by the demand presented in the school curriculum. Furthermore, the study of plane geometry is of utmost importance not only for the development of logical and abstract thinking, but also for practical application in various areas of human knowledge, playing a vital role in educational and professional training (Silva, 2024).

The qualitative approach proves to be relevant in this study, since we understand it is essential to take into account the personal and interpretive manner when producing and analyzing the data. And also because we aim to investigate the role of Educational Robotics in the mathematics learning process of students in the final years of elementary school. The data were produced at Escola Estadual Raul de Leoni, a public school in the municipality of Viçosa–MG. The research participants were 10 students² from a seventh-grade class. Two sessions of two class hours each were held during the regular mathematics class times in the afternoon. During the sessions, we had the technical and pedagogical support of the class teacher and three other members of the Group for Attention to Technologies in Education (GATE) and the Center for Specialization in Robotics (NERO)³.

The meetings were divided into two stages: in the first, an investigative activity involving Educational Robotics was carried out, and in the second, we conducted a game that we called Enigmatemático, in which we used the *Math Robot* that recognizes facial expressions through Artificial Intelligence. However, due to the volume of data and keeping in mind the objective of this article, we will address more specifically the data produced in the first stage. Table 1 provides the relationships between the theoretical foundation and the stages of the investigative activity, that is, the way each moment was conceived and carried out.

Table 1: Relationships between the theoretical foundation and the stages of the activity

Mathematical Investigations Moments		Computational Thinking	Activity Steps
1°	Exploration of the initial problem	Abstraction; Decomposition	Investigate the internal angle of the Equilateral Triangle and Square
2°	Data Organization	Algorithm; Pattern recognition	Build the Algorithm
3°	Conducting Tests	Abstraction; Algorithm	Present the Algorithm from the other group
4°	Argumentation: justify results	Algorithm; Pattern recognition	Present the Algorithm from the other group

Source: by the authors

In this investigative Activity we used the Conveyor Robot (figure 1). A robot built in the NERO laboratory with its materials, resources, and by its members. It is the result of a Course Completion Work by one of the students in the group and aims to serve students of different levels of education, as well as various research on Educational Robotics.

Figure 1: Conveyor Robot

² The class consisted of 14 enrolled students, of whom 4 were absent from both classes where the meetings took place.

³ Research groups of which the authors are members:

*GATE page in the Directory of Research Groups in Brazil on the Lattes platform. Available at: <https://dgp.cnpq.br/dgp/espelhogrupo/9583657509714030>. Accessed on: May 14, 2024.

*NERO page in the Directory of Research Groups in Brazil on the Lattes platform. Available at: <https://dgp.cnpq.br/dgp/espelhogrupo/0868223885855886>. Accessed on: May 14, 2024.



Source: prepared by the authors

Similarly, the *Tagbot* application used to control it was developed within the scope of NERO as a Scientific Initiation project by one of the members and aimed to add more functionalities to the Conveyor Robot, expanding human-technology interaction by allowing the user to interact with it in various ways. In this activity, we used the application's geometry module (Figure 2).

Figure 2: TagBot app interface — geometry module



Source: by the authors

Thus, the Tagbot Application works from the "Sequence" space in which the sequence described by the user will be issued, allowing the construction of different geometric figures by the Conveyor Robot. The sequence is built from the following commands: the robot moves a pre-programmed space forward; rotates the angle described in result; executes the sequence; corrects some step; clears the entire sequence built up until then; it interrupts the sequence at any moment, but since our purpose is precisely to analyze the sequences, we will not use this function. Therefore, these commands are assigned to the "Sequence" space as soon as you select them, and in this way the application works.

The data production procedures were: photographic records, audio and video recordings, a sheet of the activities carried out, and notes in the researcher's field notebook. In addition, we held a discussion circle in the last class, in the second meeting, to obtain feedback from the students. We clarify that the conduct of this research was approved by the Research Ethics Committee on Human Beings at the Federal University of Viçosa.⁴

⁴ Research approved by the Research Ethics Committee with Human Beings of the Federal University of Viçosa (CAAE: 75881223.5.0000.5153).

5 Results and discussions

Initially, we established a dialogue with the students to understand their prior knowledge regarding Robotics and Educational Robotics. This moment helped us to verify that, as previous studies pointed out, Robotics and other developments in digital technology have come to stay and are already part of the students' reality (Campos, 2019). The students indicated during the conversation that words such as “robot,” “Robotics,” and “programming” are not unfamiliar or unusual.

After the conversation, we explained some concepts, namely: Robotics, robot, programming, and algorithm. Next, we presented the Conveyor Robot and the *Tagbot* app that assisted in the activity, explaining the operation of both in detail. Right after, having learned about the Conveyor Robot, the app, and the operation of both, the students were challenged to build an algorithm with the steps necessary for the robot to construct a square or an equilateral triangle. The class was divided into four groups, and each group received a sheet containing, at the top, the name of the regular polygon to be constructed. In this way, one group had no knowledge of the work of the other. After completing the task, the researcher omitted the name of the polygon and swapped the algorithms so that they could execute them.

At first, when mentioning the task to be carried out by handing the activity sheet⁵ to the groups, we discussed the starting point for building the algorithm, and immediately, some students mentioned that it was necessary to find out the internal angle of the regular polygon to be constructed by the robot, initiating the first moment of the Mathematical Investigations. According to Ponte *et al.* (2009), the first moment of the Mathematical Investigations consists of recognizing the problem, exploring it, and formulating questions.

When investigating the internal angle of the polygon, the students performed the exercise of decomposing the problem, an essential part of Computational Thinking, reinforcing that there is a cognitive process that should not be restricted to scientists (Gadanidis *et al.*, 2022; Wing, 2006).

To design the algorithm, the students needed to investigate what the internal angle required for constructing the regular polygon was. In order to assist the students, protractors, rulers, and concrete materials in the shape of a square or equilateral triangle were made available so that all group members could carry out such an investigation and, subsequently, proceed with the activity. These manipulable materials, as well as the discoveries made from them, led to consistent and lasting learning (Ponte *et al.*, 2015). However, within the same group, it was possible to find students who handled the protractor with ease and others who did not know how to use it, as illustrated in Figure 3.

Figure 3: Students handling the protractor

⁵ The activity sheet provided only showed the name of the regular polygon to be constructed (square or equilateral triangle) at the top and the space needed below to complete the task.



Fonte: elaborado pelos autores

Ponte *et al.* (2015) clarify that students can surprise us regarding the level of difficulty assigned by us teachers to a certain activity. A classroom study experienced by the authors certifies that problem-solving of an investigative nature has significant relevance for Mathematics teaching, since it leads students to develop hypotheses, strengthen conjectures, explore examples, and other actions important for the development of reasoning.

This particularity reinforces the role of educators as mediators of investigations. In this study, this role was carried out by the researcher and monitors who, from the beginning of the activities, went through all the groups, mediating the action and establishing a careful dialogue, as we can observe in Figure 4.

Figure 4: Researcher and monitors acting as mediators



Source: prepared by the authors

These monitors acted as active mediators who, attentive to doubts, sought to resolve them in a way that did not compromise the development of the activity, taking care not to influence the decision of the next steps or even the final outcome (Rodrigues *et al.*, 2020; Ponte *et al.*, 1998).

An interesting fact discussed in Guiraze *et al.* (2023) is that practices involving algorithms can facilitate the performance of unplugged activities, that is, activities that do not require the use of computers, smartphones, and other digital technologies such as robots, which makes it possible to work on Computational Thinking and concepts from the field of Robotics in environments where the infrastructure is poor or limited. Unplugged activities can also be used to work beforehand on notions that will be explored through electronic equipment in order to promote the introduction of basic programming concepts, as is the case in this work. In this

initial stage of the activity, we aim to develop an intuitive notion of programming in order to facilitate the use of the application and the understanding of commands.

Practices that include Educational Robotics, even indirectly, as in this initial stage, can count on strong student engagement, since there is interaction between them and also with the teacher, which makes it possible to work even on the most abstract concepts. Thus, a training "that is not limited to content and is not centered only on programming or technological-robotic construction" can be desired (Azevedo *et al.*, 2022, p. 219).

In the case of this research, the groups discussed among themselves so that, by consensus, they could reach an answer about what the internal angle necessary to construct the regular polygon was. Subsequently, the students returned to building the algorithm, debating the next steps and how they could record them on paper. Thus, they began organizing the data, a phase related to the second moment of the Mathematical Investigations (Ponte *et al.*, 2009). At this moment, it was possible to notice that the class remained engaged in the entire activity, participating actively in the process. Even in moments when they were not directly responsible for writing, the students contributed through suggestions, corrections, and ideas, as illustrated in Figure 5.

Figure 5: Moment of discussion among the students and data organization



Source: prepared by the authors

Communication between groups was fundamental for the construction of knowledge. This collective discussion is recognized as an aspect of Mathematical communication that contributes to learning through the intertwining of ideas in which the negotiation of meanings emerges (Rodrigues *et al.*, 2020). Similarly, Educational Robotics can provide a collaborative learning space, allowing each student to contribute with their knowledge and learn from others (Campos, 2019). In these practices, we encounter proactive, engaged, and reflective students who, when facing problems as a team, practice collaborative problem solving and decision making.

The third and fourth moments of the Mathematical Investigations occurred simultaneously in this work, insofar as the students presented the ideas and discussions took place, as illustrated by figure 6. By exchanging the algorithms they had built to execute them, the groups simultaneously presented the algorithm built by their classmates to the class and argued about the lack of information, mistakes, successes, and even carried out a brief evaluation stating whether the sequence would work or not.

Figure 6: Moment of execution and presentation of the algorithms



Source: by the authors

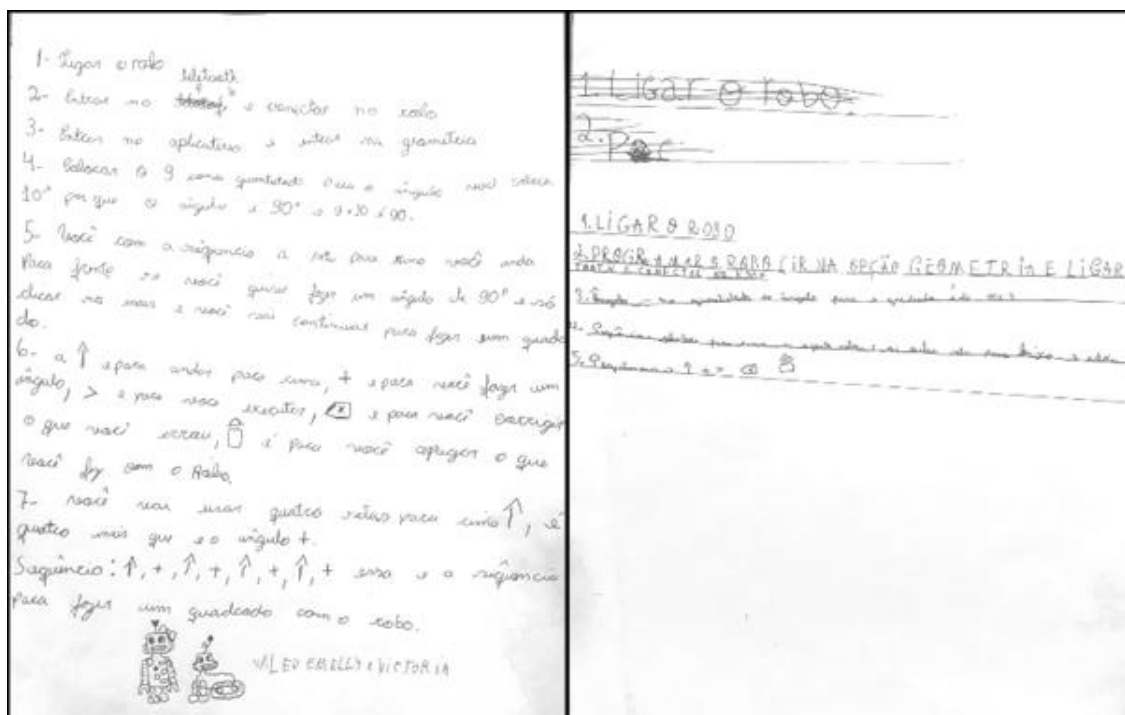
To better present their ideas, the students used the board in order to explain how they interpreted the sequence provided in the algorithm built by their classmates. Something that drew attention at this moment was the focus and participation of everyone during the presentations, since the groups debated among themselves and with the entire class.

Some sequences were not even recognized by the application, since they did not correspond to what was proposed, such as: a sequence with the command to add two angles in a row ($++$) or to move forward twice in a row ($\uparrow\uparrow$). With this, the class realized that there was an important pattern to be followed. Since the goal was to construct a regular polygon, the application would not accept sequences indicated successively to rotate the angle or add steps forward. According to Azevedo (2022, p. 44), “the recognition of patterns contributes to the identification of processes that repeat logically and orderly”.

The students understood that this programming of the Conveyor Robot also depended on the internal angle needed to construct such regular polygon. Assuming that the Robot makes movements of 10° , 12° , 15° , and 90° , being able to multiply them up to ten times, the students needed to consider how to form the 60° angle and even the 90° angle in order to explore various possibilities. At this moment of conducting tests, the students refined their ideas, analyzing whether the sequence provided by their classmate, as it was structured, was recognized by the robot or not, and then there was a discussion in search of justification for such an error or success. An important moment of the investigation was when the students developed “the ability to communicate mathematically and to reflect on their work and their argumentative skills” (Ponte *et al.*, 2009, p. 41). In addition, with the researcher’s assistance, the class was able to solidify the knowledge they had built regarding regular polygons.

Among the algorithms presented, regarding the squares, both groups paid attention to the organization of the steps. However, one of them consisted of scarce information. Figure 7 illustrates the groups’ understanding of the sequence of steps.

Figure 7: Moment of execution and presentation of the algorithms



Source: by the authors

Due to the low quality of the presented image, we provide a detailed description of the image in order to offer a more comprehensive understanding of its content and enable the reader to follow the analysis through a thorough appreciation of it (Table 2).

Table 2: Description of the image shown in Figure 7

1. Turn the robot on. 2. Enter Bluetooth and connect to the robot. 3. Enter the app and go to geometry. 4. Enter 9 as the quantity for the angle; you put 10° because the angle is 90° and 9×10 equals 90. 5. With the sequence, the up arrow moves you forward. If you want to make a 90° angle, just click the plus sign and you will continue to make a square. 6. The $\uparrow$ is to move upwards, $+$ is to make an angle, $>$ is to execute, $\otimes$ is to correct what you did wrong, $\boxtimes$ is to erase what you did with the robot. 7. You will use four up arrows $\uparrow$, which is four plus signs, representing the angle $+$. Sequence: $\uparrow, +, \uparrow, +, \uparrow, +, \uparrow, +$ This is the sequence to make a square with the robot. THANKS EMELLY and VICTORIA 	1. <u>Turn on the robot</u> 2. <u>Prog</u> 1. <u>1. Turn on the robot.</u> 2. <u>2. Program the robot (go to the geometry option, turn on Bluetooth, and connect to the robot).</u> 3. <u>3. The angle for the square is 10x9.</u> 4. <u>4. Sequence - up arrow, then we put a +, then another down arrow and put a +.</u> 5. <u>5. Sequence $\uparrow + > \otimes \boxtimes$.</u>
--	---

Source: by the authors

Note that both groups understood the activity's proposal and the characteristics of an

6- The Pac-Man mouth (>) is the button to execute the movement 7- The delete button is to correct the command  8- The trash can is to delete everything  9- You need to measure the angle of the total shape and pass it to the robot 10- You will have to click on the angle 10° and the quantity 6 11- You have to write the sequence ↑ + > but if you make a mistake you have to put  12- You need to click ↑ 3 times on this arrow + 3 times also this command and just click once on this arrow (>)	↑ + >   Angle quantity execute delete correct sides Step⑤ In the quantity you have to put 6 Step⑥ And in the angle 10° 10 x6 60 Step⑦ The sequence is: first we put arrow ↑ then the +, ↑, +, ↑, + and > ↑, +, ↑, +, ↑, +, > ↑ + ↑ + ↑ + > = 
---	--

Source: prepared by the authors

In order to make the information even more explicit, both groups used symbols. However, only the one on the right took care to indicate the sequence in the way it should appear in the application. In this way, the algorithm on the left ended up providing ambiguity and, even though they took care to describe the actions correctly, this fact made it impossible for the application to identify the sequence, since, according to the commands, the team that presented it understood that they should enter the angle 3 times (+ + +), something the application did not recognize.

During the presentation of their classmates, the class was, on one hand, attentive to the mistakes or successes of their peers and, on the other, connected to the algorithm they had received in an attempt to prepare for their own presentation. As soon as the presentations began, the students realized that it was not enough to create a sequence of steps, but that the algorithm required a set of logical-procedural and analytical rules (Azevedo, 2022).

The students repeatedly reflected on the outcome they wanted to achieve, the consequences of those steps, and the construction carried out by the Conveyor Robot, in a process of abstraction, to finally determine whether the sequence was correct or not. According to Wing (2011), the algorithm is directly related to the process of abstraction, since it is an important part of Computational Thinking that allows the student, among different skills, to exercise logical reasoning.

Due to a small technical problem with the Treadmill Robot that compromised this final part of the first meeting, we explored a little more of the third and fourth moments of the Mathematical Investigations at the beginning of the second meeting. Unlike the previous meeting held in the classroom, this one took place in the schoolyard because of the excellent lighting in the space, a factor that affects the Enigmathematic Game that would occur afterward. We noticed that, despite the change of location, the students remained engaged with the activity, showing curiosity and interest, as shown in Figure 9.

Figure 9: Continuation of the tests and exposure of the algorithms



Source: prepared by the authors

When analyzing the behavior of the Conveyor Robot to verify whether the provided sequence generated the expected result, the students developed Computational Thinking skills, maintaining a critical stance towards the robot. This stance allowed them to think about the new, that is, to develop creative students who move away from the reality of merely recombining existing information (Blikstein, 2008).

Still in this second meeting, we held a discussion circle in which the students showed interest in activities involving investigations and Robotics, as shown in Figure 10.

Figura 10: Roda de conversa



Source: prepared by the authors

A recurring theme in the students' statements was the interest in practices different from the usual ones and, moreover, leaving the traditional classroom space, which made everything more interesting in their view. One of the students reported having enjoyed the activity because it helped to understand the content and justified it by saying:

Student X: Because we had to find out how to make a triangle, a square [...]

Another student adds:

Student Y: That's right, and then we had to know what the angle was, and then nine times ten gave ninety degrees (Dialogue between the students, 2025).

Regarding the mathematical content studied, the students mentioned geometric shapes, multiplication, addition, and angles. The class teacher added by reminding them about divisors, a topic covered at the beginning of the school year that converged with the content studied during the meetings. The students pointed out multiples, and soon a dialogue arose relating multiples and divisors.

The Teacher stated: Ninety is nine times ten, so nine is a divisor of ninety

Student A: And ten is also a divisor of ninety

Student B: Ninety is also a multiple of nine

Student C: And of ten

Student D: And of zero too (Dialogue between the class teacher and the students, 2025).

By exploring the properties and the relationships between points, angles, and two-dimensional figures within the theme of regular polygons, students developed critical reasoning and problem-solving skills, assisting in the performance of practical everyday tasks from the simple planning of a physical space to the creation of technical drawings (Silva, 2024).

With this study, we observed the significant engagement of students when Educational Robotics was incorporated into Mathematics class activities, offering an interactive and practical approach to learning different concepts, even the most complex ones (Azevedo, 2022; Campos, 2019; Gadanidis *et al.*, 2022; Pereira *et al.*, 2023). The playful and challenging nature of these activities contributed to a dynamic learning environment where students felt motivated, enthusiastic, committed, and responsible for their own educational process.

Therefore, the integrated work between Computational Thinking, Mathematical Investigations, and Educational Robotics contributed to the engagement, autonomy, and development of students' critical thinking. The practices provided students with opportunities to explore mathematical concepts in a concrete and interactive way, favoring the formulation, execution, and analysis of algorithms. It was observed that the students were motivated, collaborative, and capable of reflecting on their problem-solving strategies, indicating that the integration of these areas stimulates not only mathematical understanding but also critical computational thinking skills and autonomy in learning (Ashtiani & Demarchi, 2025). Thus, Educational Robotics is configured as a pedagogical tool capable of articulating investigation, creativity, and structured reasoning, enhancing the formative process in Mathematics in the Final Years of Elementary School.

6 Final considerations

Given the need for reflection on the role of Educational Robotics in learning, this study aimed to investigate the role of Educational Robotics in the formative process in Mathematics of students in the Final Years of Elementary School. In this way, we connected Educational Robotics to Mathematical Investigations through an intentional activity on the construction of algorithms.

Regarding the question that guided this article: "How can the integrated work between Computational Thinking, Mathematical Investigations, and Robotics in Education contribute to students' engagement, autonomy, and development of critical thinking, especially in the process of creating and analyzing algorithms?", we highlight that, by linking Robotics to educational processes, it is possible to contribute to the formation of active, critical, and creative citizens, since it can provide an environment in which students find themselves questioning facts that

they previously only accepted when solving an exercise. Thus, a space in which curiosity and discovery are indispensable elements can result in inquisitive students who exercise communication and organization of ideas.

We must pay attention, however, to some limitations that run through this scenario and establish a plan aimed at mitigating unforeseen events and overcoming obstacles. Among these limitations are technical problems that may occur with the robots, as happened during this study. To work around this situation, it is necessary that the time for activities is very well divided, because, in this way, it is possible to rearrange them quickly. Furthermore, for future studies, it becomes necessary to consider the number of robots in relation to the number of students, as well as accessible materials and the conditions and contexts of teaching work. It is worth emphasizing that other polygons, such as other school levels, can be explored.

The results suggest that Educational Robotics can act in the mathematical formative process as an important tool capable of enhancing it, as it can arouse students' interest, making them part of this process of knowledge construction. Furthermore, activities with Robotics and Mathematical Investigations can contribute to the active participation of students, transforming the classroom into an interactive, curious, and enjoyable environment. Such practices can foster, among other things, cognitive and socio-emotional skills, as well as Computational Thinking, which allows promoting different processes such as problem-solving, so important in Mathematics and other areas. Thus, it becomes necessary to reflect on Robotics within the scope of Education, aiming to foster the learning process as a whole.

Acknowledgements

We thank the National Council for Scientific and Technological Development (CNPq) for the master's scholarship (Linked to project 408155/2022-1 - Application of Reinforcement Learning Techniques in the Navigation of Autonomous Vehicles) of the first author.

References

- Ashtiani, A. M. & Demarchi, T. (2025). Computational Thinking with Python in Mathematics Education: Interdisciplinary Connections and Challenges in the New High School Curriculum. *Revista Internacional De Pesquisa Em Educação Matemática*, 15(2), 1-19. <https://doi.org/10.37001/ripem.v15i2.4463>
- Azevedo, G. T. (2022). *Processo Formativo em Matemática: Invenções Robóticas para o Parkinson*. 2022. 213 f. Tese (Doutorado em Educação Matemática) — Instituto de Geociências e Ciências Exatas, Universidade Estadual Paulista (Unesp), Rio Claro, SP.
- Azevedo, G. T.; Maltempi, M. V. & Powell, A. B. (2022). Contexto Formativo de Invenção Robótico-Matemática: Pensamento Computacional e Matemática Crítica. *Bolema: Boletim De Educação Matemática*, 36(72), 214-238. <https://doi.org/10.1590/1980-4415v36n72a10>
- Benakouche, T. (1999). Tecnologia e sociedade: contra a noção de impacto tecnológico. *Cadernos de Pesquisa*, (17), 1-28.
- Blikstein, P. (2008). *O pensamento computacional e a reinvenção do computador na educação*, Education & Courses.
- Bogdan, R. & Biklen, S. (1994). *Investigação Qualitativa em Educação*. Portugal: Porto Editora.
- Brasil. Ministério da Educação. (2018). *Base Nacional Comum Curricular*. Brasília, DF.

- Campos, F. R. (2019). *A robótica para uso educacional*. São Paulo, SP: Senac Editora.
- Corradi, D. K. S. (2011). Investigações Matemáticas. *Revista da Educação Matemática da UFOP*, 1, 162-175.
- Costa, J. (2009). Tecnologia digital: verbete. In: C. Marcondes Filho. (Org.). *Dicionário de comunicação*. (2. ed., p. 570 – 571). São Paulo, SP: Paulus Editora.
- D'Ambrosio, U. (2013). *Educação matemática: da teoria à prática* (23 ed.). Campinas, SP: Papirus Editora.
- Dolce, O. & Pompeo, J. N. (2013). *Fundamentos da matemática elementar 9: Geometria plana* (9. ed.). São Paulo, SP: Atual Editora.
- Gadanidis, G.; Javaroni, S. L.; Santos, S. C. & Silva, E. C. (2022). Computing in Mathematics Education: Past, Present, and Future. In: M. Danesi. (ed.). *Handbook of Cognitive Mathematics*. (v. 2-2, Capítulo 27, p. 805-842). Cham: Springer Publisher.
- Goldenberg, M. (2007). *A arte de pesquisar: como fazer pesquisa qualitativa em ciências sociais* (10. ed.). Rio de Janeiro, RJ: Record Editora.
- Guiraze, J. A.; Singo, F. F. & Chin, M. R. (2023). Pensamento computacional para a formação do profissional do futuro. *Revista Multidisciplinar do Nordeste Mineiro*, 6(1), 1-11.
- Lévy, P. (2010). *Tecnologias da Inteligência: o futuro do pensamento na era da informática* (2. ed.). São Paulo, SP: Editora 34.
- Lüdke, M. & André, M. E. D. A. (2013). *Pesquisa em Educação: Abordagens Qualitativas* (2. ed.). Rio de Janeiro, RJ: E.P.U. Editora.
- Martins, D. J. S. & Oliveira, F. C. S. (2023). Pensamento computacional para crianças por meio do projeto de extensão academia hacktown. *Caderno Cedes*, 43(120), 33-44. <https://doi.org/10.1590/CC271373>
- Navarro, E. R. & Sousa, M. C. (2023). *Qual o conceito de pensamento computacional para a Educação Matemática?* São Paulo, SP: Dialética Editora.
- Oliveira, A. M. R. & Macêdo, J. A. (2025). Desafios de acesso e inovação pedagógica com tecnologias digitais no ensino de Matemática: contribuições do modelo TPACK. *Revista Internacional De Pesquisa Em Educação Matemática*, 15(2), 1-21. <https://doi.org/10.37001/ripem.v15i2.4526>
- Papert, S. (2008). *A máquina das Crianças: repensando a escola na era informática*. Porto Alegre, RS: Artes Médicas. Publicado originalmente sob o título de: *The children 's machine: rethinking school in the age of the computer*. New York, NY: Basic Book.
- Papert, S. (1980). *Mindstorms-Children, Computers and Powerful Ideas*. New York, NY: Basic Books, Inc.
- Pereira, J. M.; Oliveira, R. M. S.; Andrade, S. C. F.; Romulo, T. C. S.; Santos, S. C.; Faria, R. W. S. C. & Brandão, A. S. (2023). Robotics as a Possibility for Exploring Laterality in Early Childhood Education. In: *Analls of the 10th Latin American Robotics Symposium (LARS), 15th Brazilian Symposium on Robotics (SBR) and 14th Workshop on Robotics in Education (WRE)* (p. 678-682). Salvador, BA.
- Ponte, J. P.; Brocardo, J. & Oliveira, H. (2009). *Investigações Matemáticas na Sala de Aula* (2. ed.). Belo Horizonte, MG: Autêntica Editora.
- Ponte, J. P.; Oliveira, H.; Brunheira, L.; Varandas, J. M. & Ferreira, C. (1998). O trabalho do

- professor numa aula de investigação matemática. *Quadrante*, 7(2), 41-70. <https://doi.org/10.48489/quadrante.22709>
- Ponte, J. P.; Quaresma, M.; Mata-Pereira, J. & Baptista, M. (2015). Exercícios, problemas e explorações: Perspectivas de professoras num estudo de aula. *Quadrante*, 24(2), 111-134. <https://doi.org/10.48489/quadrante.22920>
- Rodrigues, C.; Ponte, J. P. & Menezes, L. (2020). Práticas discursivas de professores de Matemática na condução de discussões coletivas. *Quadrante*, 29(2), 24-46. <https://doi.org/10.48489/quadrante.22575>
- Romulo, T. C. S. (2025). *Implicações da Robótica Educacional no Processo Formativo em Matemática*. 2025. 126 f. Dissertação (Mestrado em Educação) — Universidade Federal de Viçosa, Viçosa, MG.
- Romulo, T. C. S.; Faria, R. W. S. C. & Brandão, A. S. (2024). Uso da Robótica Educacional no processo de aprendizagem da Geometria Plana nos Anos Finais do Ensino Fundamental. In: *Anais do 9º Seminário Internacional de Pesquisa em Educação Matemática* (p. 1-13). Natal, RN.
- Santos, D. T.; Santos, S. C. & Javaroni, S. L. (2023). O conceito de tecnologia e seres-humanos-com-mídias: aspectos epistemológicos da cibernética e educação matemática. In: M. C. Borba; J. F. Xavier & T. A. Schunemann. (Org.). *Educação Matemática: múltiplas visões sobre tecnologias digitais*. (v. 1, 1. ed., Capítulo 2, p. 23-38). São Paulo, SP: Livraria da Física.
- Silva, R. C. C. (2024). *A inserção da arte na educação matemática: utilização das obras de Escher para ensinar geometria espacial*. 2024. 46 f. Trabalho de Conclusão de Curso (Licenciatura em Matemática) — Universidade Federal de Pernambuco, Caruaru, PE.
- Vieira-Pinto, Á. (2005). Capítulo IV: Tecnologia. In: Á. Vieira-Pinto. *O conceito de tecnologia*. (v. 1, p. 219-355). Rio de Janeiro, RJ: Contraponto Editora.
- Wing, J. M. (2006). Computational thinking: the beginning. *Communications of the ACM*, 24(3), 33-35. <https://doi.org/10.1145/1118178.1118215>
- Wing, J. M. (2011). Research Notebook: Computational Thinking: what and why. *The link*, 6, 20-23.