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Micro-stories, Robotic Coding, Digital Applications, and Augmented Reality to Enhance Children's Computational Thinking

Microrrelatos, codificación robótica, aplicaciones digitales y realidad aumentada para potenciar el pensamiento computacional infantil

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ABSTRACT
This research evaluates the potential of an educational intervention aimed at developing Computational Thinking (CT) in preschool students aged 4 to 6 years (N=82). The proposal is a playful approach based on a story featuring a robot, which students must code to navigate a physical scenario and overcome various challenges by interacting with digital applications and Augmented Reality (AR). The study follows a pre-experimental design with a descriptive and comparative methodology, using a pre-test/post-test to assess CT levels based on key skills: algorithmic thinking, generalization, abstraction, decomposition, and evaluation. The results highlight the effectiveness of the proposal in enhancing CT in most students, regardless of gender and age. Students with Special Educational Needs and Disabilities (SEND) also showed an improvement in their CT skills, albeit with greater challenges. All participants were introduced to robotic coding, which contributed to strengthening their spatial orientation, laterality, counting skills, hand-eye coordination, logical reasoning, and more. In conclusion, the use of a playful narrative fostered students' connection with the story and empathy with the characters, enhancing their engagement with the proposed tasks and reducing their complexity.

RESUMEN
La presente investigación evalúa la potencialidad de una intervención educativa para desarrollar el Pensamiento Computacional (PC) en alumnado de Educación Infantil de 4 a 6 años (N=82). Se trata de una propuesta lúdica apoyada en un relato protagonizado por un robot, que el alumnado debe codificar para avanzar por un escenario físico y superar distintos desafíos interactuando con aplicaciones digitales y de Realidad Aumentada (RA). La investigación es pre-experimental, adopta una metodología descriptiva y comparativa utilizando un pre-test/post-test que registra el nivel de PC a partir de sus habilidades plasmadas: pensamiento algorítmico, generalización, abstracción, descomposición y evaluación. Los resultados evidencian la contribución de la propuesta para incrementar el PC de la mayoría del alumnado, independientemente de la variable género y edad. El alumnado con ACNEAE también ha incrementado su nivel de PC aunque con mayores dificultades. Todos se iniciaron en la codificación robótica, lo que contribuyó a activar e impulsar su orientación espacial, lateralidad, capacidad de conteo, coordinación óculo-manual, razonamiento lógico, etc. A modo de conclusión, se subraya que la utilización de una narrativa lúdica ha promovido la conexión del alumnado con la historia y la empatía con los personajes, favoreciendo su engagement con las tareas propuestas y minimizando su complejidad.

KEYWORDS PALABRAS CLAVE
Computational Thinking, Micro-stories, Digital Apps, Augmented Reality, Early Childhood Education.
Pensamiento computacional, microrrelatos, app digitales, realidad aumentada, Educación Infantil.

1. Introduction

Since the Horizon Report, Teaching and Learning Edition (Pelletier et al., 2022) and the UNESCO ICT Competency Framework for Teachers (UNESCO, 2019), the promotion of digital competencies among both teachers and students has been emphasized as essential for interacting in an increasingly technologized world. Computational Thinking (CT) has become a fundamental logic for interacting with increasingly sophisticated machines. In this regard, DigComp (Vuorikari et al., 2022) identifies CT as one of the key components in fostering digital competence.

CT is understood as an individual's ability to solve problems systematically, creatively, and collaboratively, with the support of digital resources. It encompasses dimensions such as algorithmic thinking, generalization, abstraction, and evaluation (Wing, 2006). According to Shute et al. (2017), it is a skill for solving problems effectively and efficiently—algorithmically—with or without the aid of computers, using various resources applicable across different contexts. From a pedagogical perspective, authors such as Montuori et al. (2024) point out that computational thinking (CT) can foster fundamental cognitive skills in early childhood, such as logical thinking, creativity, and autonomy. However, according to Yang et al. (2024), there is a risk of prematurely instrumentalizing learning by prioritizing programming languages or technological tools over the holistic development of students. Therefore, the focus should be on providing playful and meaningful experiences that respect the principles of child development.

One of the key discussions in the current literature on CT revolves around whether it should be considered a transversal competence—similar to critical thinking or problem-solving—as suggested by Dagiené et al. (2024), or whether it represents a form of advanced digital literacy, as argued by Pajchel et al. (2024). Proponents of the former view argue that CT can be integrated into various curricular areas such as mathematics, science, or even language learning, supporting an interdisciplinary approach (Ouaazki et al., 2024). On the other hand, authors such as Akramova et al. (2024) and Yuberti et al. (2024) associate CT with skills specific to the STEM field and suggest that its implementation requires a conceptual foundation that may exceed the cognitive capacities of younger students.

However, CT can be stimulated at this stage through interventions involving robotic programming (Canbeldek & Isikoglu, 2023), which entails planning tasks to activate the robot, coding its movements in space, and solving encountered problems in a logical and coherent manner. This practice promotes understanding and abstraction by helping children associate the robot's buttons with their corresponding actions (Zhang et al., 2020). Additionally, it activates the ability to generalize, enabling children to recognize patterns and identify the optimal sequence for executing pre-set commands (Silva et al., 2023). Moreover, interacting with the robot allows for an evaluation of programmed actions, providing feedback on successes and errors and offering opportunities for adjustments.

In educational contexts, stories are commonly used in early childhood as vehicles to facilitate learning across different domains. Their immersive quality fosters children's emotional engagement with characters and enhances task engagement by allowing them to take on protagonist roles (Leoste et al., 2021). In this regard, various experiences have incorporated robots as protagonists in fictional narratives, integrating curriculum content and promoting CT through playful challenges that motivate young learners in their learning process (Chang et al., 2023; Chen & Lee, 2023).

Additionally, digital applications and Augmented Reality (AR) enable direct interaction with scenarios and characters to solve problems such as identifying elements based on specific characteristics (colors, sizes, shapes, etc.), thereby enhancing abstraction and generalization skills. Immersive scenario visualization also broadens educational activities by stimulating students' spatial orientation as they navigate digital fictional environments (Işik et al., 2024). Furthermore, assuming different roles within predetermined narratives enhances engagement in the story's development, as students become involved in conflict resolution through various activities. Clearly, these applications can activate CT by fostering multisensory stimulation in problem-solving scenarios while providing immediate feedback on performance.

Thus, this study aims to determine whether an educational intervention combining robotic programming, digital applications, and AR—integrated through micro-stories—contributes to the development of Computational Thinking (CT) in preschool students.

2. Digital Applications, AR, and Robotics in Micro-Stories to Activate Computational Thinking

CT has emerged as a key approach in educational innovation, especially in early childhood, showing strong connections with pedagogical trends such as constructivism, Challenge-Based Learning (CBL), and the STEAM approach. From Papert's constructionist perspective (1980), learning is strengthened when knowledge is actively constructed through the manipulation of objects. This is closely related to the activation of CT through playful activities in which children must interact with physical and/or digital elements to carry them out. In addition, the incorporation of micro-stories allows for the contextualization of challenges that encourage planning, sequencing, and problem-solving, as proposed in CBL (Nawawi et al., 2024). The STEAM approach, in turn, connects different areas of knowledge through creative, collaborative, and meaningful experiences, contributing to an integrative view of CT (Yuberti et al., 2024). However, it is essential to adopt a critical perspective on CT as an educational construct, distinguishing between general cognitive skills—such as logic and problem-solving (Singh & Kaunert, 2024)—and specific computational skills—such as programming (Canbeldek & Isikoglu, 2023).

The use of micro-stories to activate CT also makes activities more understandable and emotionally engaging by helping students connect with their prior knowledge and experiences—either by incorporating emotional robots as narrators (Antunes et al., 2022) or by using concrete narratives to increase students' involvement in the story's plot (Yang et al., 2023). According to narrative learning theories (Bruner, 1990), children structure the world through stories. Therefore, giving a robot a mission to solve a problem or conflict within a story can enhance their motivation and comprehension, giving meaning to their actions. Furthermore, based on the theory of meaningful learning (Ausubel, 1963), stories act as advance organizers, generating non-arbitrary connections between new information and what is already known. Thus, structuring CT-stimulating activities around micro-stories not only encourages students to engage with those activities, but to do so with a clear purpose or mission—such as helping a character or solving a specific situation—while becoming emotionally invested in their actions (Yang, 2024).

The interactivity offered by digital applications, along with the recreation of scenarios and challenges, fosters user immersion and engagement in performing various tasks or solving simple problems aimed at stimulating Computational Thinking (CT) (Dorouka et al., 2020; Shanmugam et al., 2019). Augmented Reality (AR), in turn, allows for the superimposition of 3D virtual elements onto the real world, facilitating the assimilation of complex concepts and processes while activating spatial thinking through multisensory experiences. This reduces students' cognitive load by making abstract elements more tangible (Işik et al., 2024). However, the combined use of digital applications and AR must be harmonized within a coherent narrative, requiring a prior selection process that justifies its integration (Dietz et al., 2021; 2023). In this regard, augmented digital micro-stories can be used, where characters placed in playful scenarios present challenges to students, fostering engagement and emotional involvement with the story itself (Triantafyllou et al., 2024).

Students' empathy with story protagonists—where they must intervene to help them achieve their goals—is enhanced when digital and AR resources facilitate the development of CT. However, there are few educational applications that incorporate micro-stories specifically designed to develop CT (Yadav & Chakraborty, 2023). Therefore, it is essential to carefully select applications that include activities designed to stimulate CT-related skills (Utesch et al., 2020), such as problem-solving through abstraction, generalization, algorithmic thinking, and evaluation strategies. These applications should also allow for the analysis of students' progress and difficulties, enabling them to learn from their mistakes.

CT can be activated in early childhood education (ages 3–6) by presenting activities that align with a cohesive narrative, fostering: *Abstraction* skills*,* through activities like assembling puzzles, classifying objects by matching them with their shadows, identifying color, shape, and size patterns, etc.; *Generalization* skills, by grouping elements based on similarities, playing memory-matching games, and associating icons, words, or images according to their semantic categories; *Algorithmic thinking*, through tasks that require following predefined steps, sequencing elements, completing series, and identifying multiple solutions to a problem (e.g., choosing the shortest path to a goal, identifying pieces that fit a given space, or constructing blocks); Task *decomposition* and *evaluation* skills, through counting activities, basic addition and subtraction, comparing solutions, spatial orientation exercises, and movement-based tasks (e.g., moving objects forward, backward, left, or right by following instructions and verifying their accuracy).

Additionally, using robots as protagonists in micro-stories is becoming increasingly common for activating CT in early childhood (Bravo et al., 2021; Hu et al., 2022; Tengler et al., 2021). This requires students to program the robot's movements to navigate a scenario and overcome challenges throughout the story (Bono et al., 2022). Programming robots with basic commands (forward, backward, turn right, turn left, etc.) fosters algorithmic thinking, as students must plan the robot's path to solve problems encountered while interacting with digital resources (Papadakis, 2022) and/or AR. This also strengthens logical reasoning, as students must count the number of steps or turns needed (forward, turn right, left, etc.).

At the same time, abstraction skills are stimulated, as students must understand the robot's role in the story while orienting themselves in space and linking each movement to the corresponding button. Generalization skills are also reinforced as students recall the story and tasks they need to complete. This entire process includes continuous evaluation, allowing students to adjust their problem-solving strategies and redefine their approach as they progress through the activity.

3. A Playful Intervention to Stimulate CT: “Cleaning the Turtle’s Home”

The designed intervention integrates digital resources, AR applications, and a robot to stimulate Computational Thinking (CT) in early childhood through interaction with the characters of a micro-story placed on a custom-designed mat (Figure 1). The story begins with Tina, a sea turtle who lives in the ocean with her family. One day, Tina realizes that her home is in danger: plastics pollute the sea, corals lose their color, and some of her marine friends face difficulties. Tina decides to embark on a mission to save her home and restore life and beauty to the reef. To achieve this, she needs the help of the students, who will be her companions in this adventure.

To introduce the story, the narrative starts with the animated short film *“Turtle Journey: Our Oceans Are in Trouble”*, a creation of Greenpeace and the award-winning animation studio Aardman (watch at https://cutt.ly/Vw4FHQXR). This short film serves as the starting point for the game, where children have the opportunity to intervene to restore Tina’s habitat.

Figure 1

Designed game

Source: Own elaboration

The students’ task is presented through a video designed with the Powtoon app, where Tina explains her mission and asks them to join her in solving challenges and returning home. As Tina moves forward, she encounters an ocean full of plastics that block her path. At this point, students must use the AR app *Plastic Ocean* (https://bit.ly/3NFxKRL) to "collect" the plastics from the ocean within a holographic environment by interacting with a tablet, clearing the way so that Tina can swim freely and continue her journey (Figure 2). Specifically, they must visually identify the plastics and click on them, activating their generalization skills, as the details vary (location, type of plastic, affected species), and users must recognize common patterns to classify the waste.

Figure 2

Intervention with the AR app Plastic Ocean

Source: Own elaboration

During her journey, Tina encounters several marine animals that need help to free themselves from the surrounding waste. Students must use the AR app *Ocean 4D+* (https://cutt.ly/7w7ARcz0) to identify the animals. Each animal explains its characteristics, diet, habitat, reproduction, and how marine pollution affects its life. The explorers describe what they learn, helping Tina better understand how to protect them. This stimulates their abstraction skills, as when observing 3D animals, students must recognize the shapes, colors, sizes, and movements of the creatures they encounter, being able to rotate, zoom in, explore, and manipulate them to identify their characteristics (Figure 3).

Figure 3

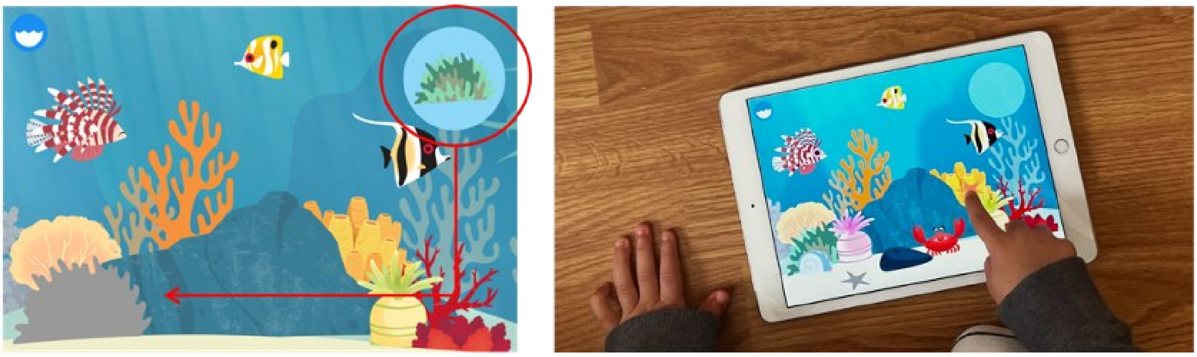
Intervention with the AR app Ocean 4D+

Source: Own elaboration.

Later, with the *Marco Polo* app (https://cutt.ly/0w7ATfzt), children must match each fish or marine element with its shadow to rebuild the coral reef. This stimulates the three main CT skills: *Abstraction*, by correctly matching fish or marine elements with their silhouette regardless of their colors; *Generalization*, by recognizing common patterns between different animal shapes and their shadows, promoting the transfer of strategies to similar cases; *Algorithmic thinking*, by establishing a logical sequence of steps: observing each animal's characteristics, comparing them with the available shadows, and selecting the correct one, solving the problem in a structured and efficient way. This activity fosters all CT skills in a playful manner (Figure 4).

Figure 4

Intervention with the Marco Polo app



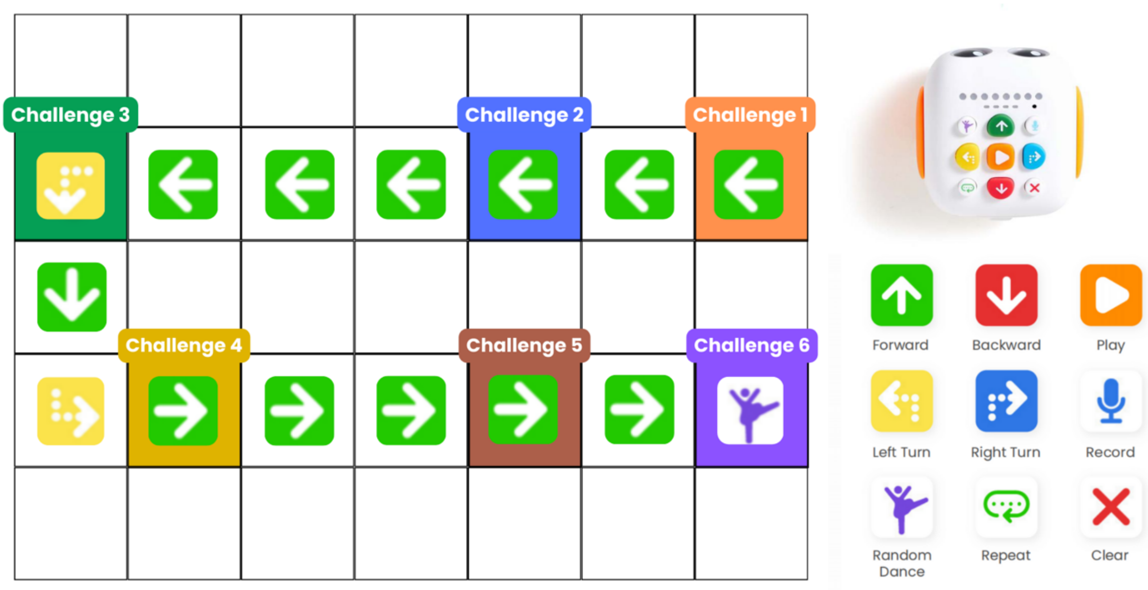
Source: Own elaboration

To complete the described activities, students must move the Tale-Bot robot across the grid on the mat, following a pre-established itinerary that requires coding its movements to reach the different activities. To do this, they must sequence the trajectory by counting the movement grids and using the corresponding buttons to move forward and make the necessary turns based on the robot's coding (Figure 5).

Thus, this intervention aims to determine the extent to which CT develops in early childhood students by using a micro-story featuring a robot as a teaching resource. Children engage in activities by interacting with digital and AR applications to contribute to the happy ending of the story.

Figure 5

Coding process integrated into the itinerary



Source: Own elaboration

4. Methodology

This research is part of the Robot-Digital StoryTelling project: *immersive playful narratives starring robots that enhance computational thinking*, funded by the University of Oviedo (2024-2025). Specifically, it focuses on analyzing whether the described educational intervention fosters the development of Computational Thinking (CT) in early childhood. It is an empirical pre-experimental study, of a descriptive and comparative nature, with an exploratory and analytical approach, as classified by Cohen et al. (2011). The adopted design uses a pre-test/post-test method to measure students' CT levels before and after participating in the intervention, which is based on a game where they interact with a robot as the protagonist of the narrative.

This methodological approach was selected due to its suitability for evaluating the impact of an educational intervention in a naturalistic context, where random assignment and the creation of a control group were not feasible for ethical and organizational reasons. Compared to more robust methodologies such as quasi-experimental or experimental designs, the pre-experimental approach allows for the collection of preliminary evidence on the effectiveness of the proposed intervention, enabling its implementation in real-world settings without significantly disrupting school dynamics. It is worth noting that several strategies were adopted to minimize bias resulting from the absence of a control group: a) methodological triangulation through the combination of quantitative instruments (pre-test/post-test and CT-Robot-DST) and qualitative tools (systematic observation); b) standardization of the intervention protocol to ensure consistency in its application; and c) rigorous statistical analysis using non-parametric tests and multiple regression to control for the influence of confounding variables.

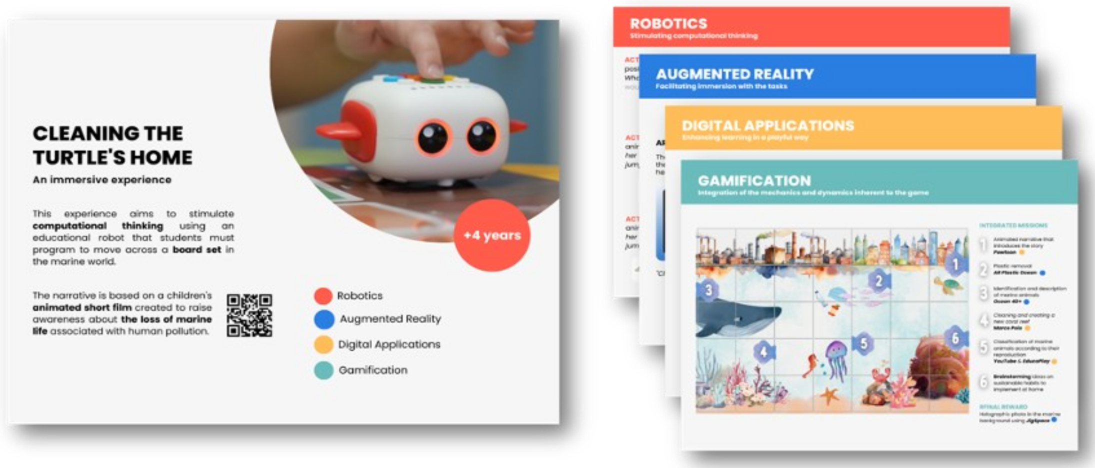
4.1. Sample

The sampling was intentional and non-probabilistic, conditioned by the participation of 4- to 6-year-old students from C.P. La Vallina (N=82), with prior authorization from their families. 58.6% were boys, and 41.5% were girls. Their ages were distributed as follows: 4 years old (24.4%), 5 years old (59.7%), and 6 years old (15.9%). 84.1% had a neurotypical development, while 15.9% were Students with Specific Educational Support Needs (SESN): 12.2% had developmental delay, 2.4% had a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD), and 1.2% had Autism Spectrum Disorder (ASD).

It is important to highlight that none of the participants had prior experience with robotics. After obtaining approval from the ethics committee of the University of XX (37_RRI_2024), the purpose and procedures were explained to teachers and families (Figure 6).

Figure 6

Explanatory document (https://cutt.ly/Ze7scD3e)

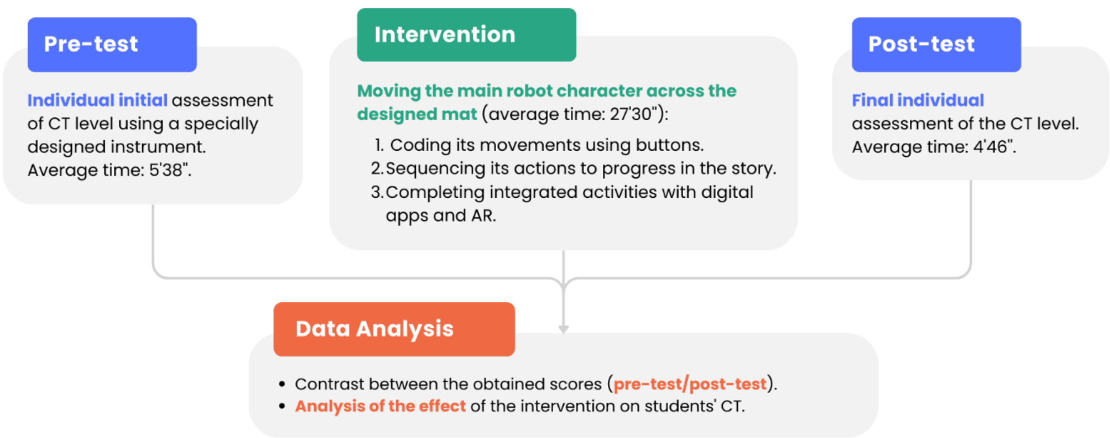


Source: Own elaboration.

4.2. Procedure and Data Analysis Techniques

Figure 7

Research phases



Source: Own elaboration

A statistical analysis was conducted based on descriptive analysis, using percentages, means, and standard deviations. After performing the Kolmogorov-Smirnov test, it was confirmed that the sample did not meet normality criteria ($p<0.001$ in all items), which is why non-parametric tests were used for subsequent comparisons. The Wilcoxon test was applied to compare pre-test and post-test results. Mean comparisons were conducted using the Mann-Whitney U test for dichotomous nominal variables (gender and presence/absence of SESN) and the Kruskal-Wallis H test for polytomous nominal variables (age). Finally, multiple linear regression analysis was performed to determine the extent to which the skills activated during the intervention could predict CT. All statistical analyses were carried out using SPSS-V26.

To ensure the neutrality, standardization, and validity of the data collection procedure, an intervention protocol was established that included the following aspects: a) each individual session lasted approximately 27 minutes and 30 seconds; b) a total of 16 sessions were conducted over the course of 4 weeks; c) evaluation conditions were standardized, taking place in the students' regular classroom, without the presence of any distracting elements and using the same materials and technological resources that students were already familiar with and used regularly; d) the instruments were administered by a single researcher, ensuring greater consistency in the evaluation. This researcher had been previously trained in the use of the instruments and in the dynamics of the intervention, thereby ensuring objectivity in data collection.

4.3. Instruments

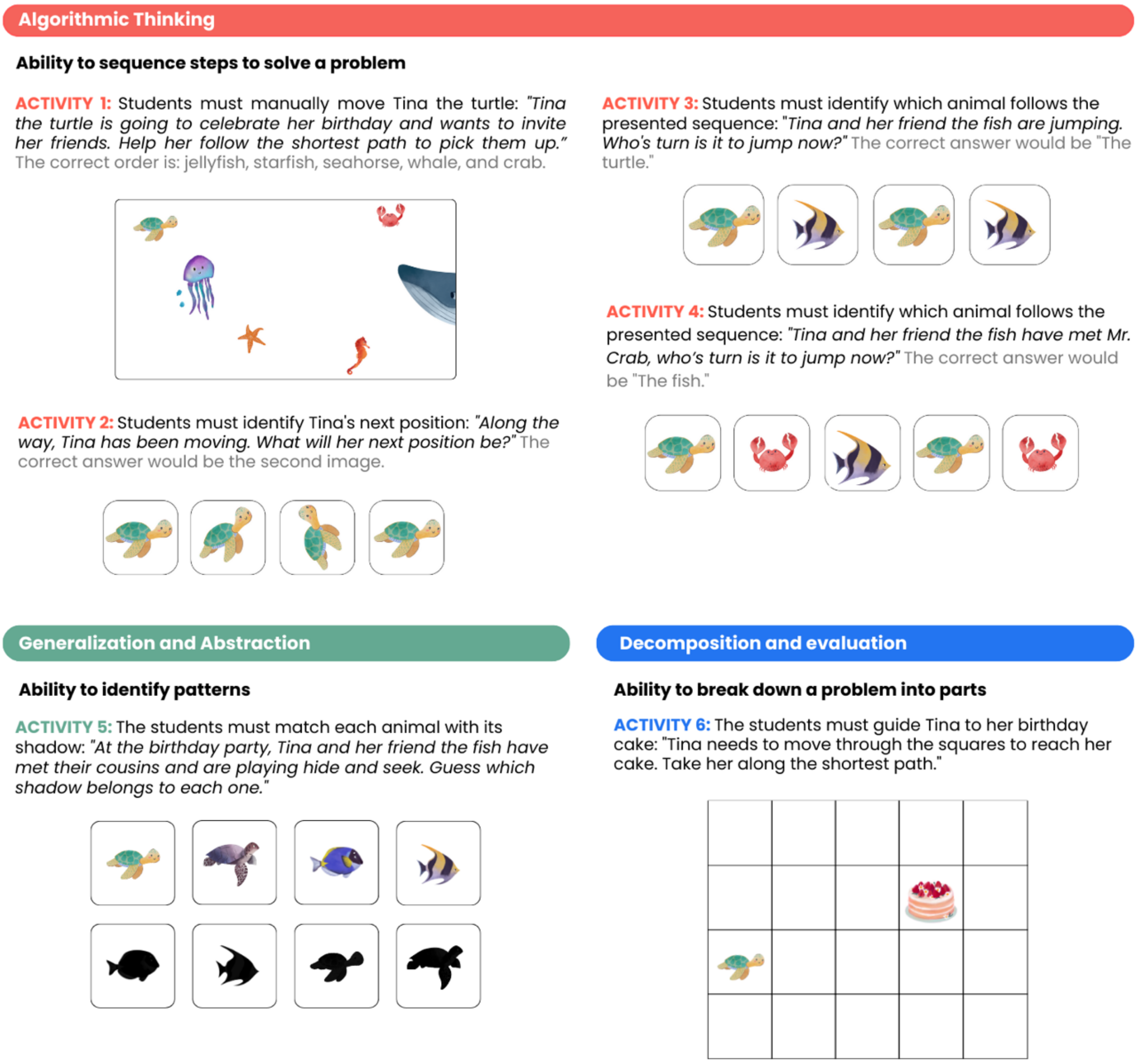
4.3.1. Computational Thinking Assessment Test (Pre-test/Post-test)

The instrument used to measure the Computational Thinking (CT) level of Early Childhood Education students (ages 3-6) integrates a series of activities adapted from the Bebras Project (https://www.bebras.org/) (Zapata et al., 2024), with reduced complexity, as the original version is designed for Primary Education (ages 6-12). The instrument development process was carried out in four phases: 1) selection of items from the original tests that assessed key CT skills (algorithmic thinking, generalization, abstraction, decomposition, and evaluation); 2) graphic and narrative redesign of the activities to adapt them to the cognitive, emotional, and contextual characteristics of children aged 4 to 6, integrating them into the story used in the intervention; 3) content validation through expert judgment by specialists in Early Childhood Education and Educational Technology, who evaluated the relevance, clarity, and appropriateness of each item; and 4) testing with a group of 2 boys and 2 girls to ensure the appropriateness of the activities, confirming their functionality, age suitability, and alignment with the educational objectives of the intervention.

After this process, the final instrument consists of six activities presented on sheets that depict the elements and characters from the described playful narrative. The activities encompass tasks associated with the theoretical dimensions intrinsic to CT (Vuorikari et al., 2022), such as algorithmic thinking (sequencing and comprehension), generalization, and abstraction, along with decomposition and evaluation (Figure 8).

Figure 8

Activities used to assess CT level (Pre-test/Post-test)



Source: Own elaboration

To ensure the ecological validity of the intervention, the activities were designed to resemble real-life situations that students might encounter, and they were embedded within a micro-story. The assessment of the activities was conducted individually, following the rubric described in Table 1.

Table 1

Evaluation Rubric for Pre-test/Post-test Activities

Activity	Very Low (1)	Low (2)	Medium (3)	High (4)
A1. Indicate the shortest path for the turtle	Presents an erratic path	Chooses an orderly path but starts with the crab	Follows the short path but skips some animals	Indicates the shortest path and starts with the jellyfish
A2. Anticipate the next position	Unable to anticipate	Anticipates correctly after several attempts	Anticipates correctly on the second attempt	Anticipates correctly on the first attempt
A3. Identify the sequence (I)	Points to the fish	Points to the turtle after several attempts	Points to the turtle on the second attempt	Points to the turtle

Activity	Very Low (1)	Low (2)	Medium (3)	High (4)
A4. Identify the sequence (II)	Points to the turtle or the crab	Points to the fish after several attempts	Points to the fish on the second attempt	Points to the fish
A5. Associate animals with their shadows	Does not associate	Associates 1-2 animals with their shadows	Associates 3 animals with their shadows	Associates all animals with their shadows
A6. Guide the turtle to the cake	Takes a diagonal path, ignoring the grid	Advances linearly but does not make the turn	Takes a correct but long path	Takes a correct and short path

Source: Created by the author

The instrument was administered individually in a controlled environment, with visual and verbal support from the researcher, following a standardized protocol.

4.3.2. Assessment instrument for Computational Thinking during an interaction supported by Robot-DST (CT-Robot-DST)

To record the level of CT displayed by the students during the execution of the playful activities conducted in the intervention with the robot, the CT-Robot-DST instrument was designed and validated. Its development began with a systematic review of previous instruments used in similar studies, identifying measurable indicators—based on observation—linked to the dimensions of CT. These indicators were inspired by those used in other research focused on assessing CT in early childhood (Berson et al., 2023; Ching & Hsu, 2023; Yang, 2024; Zeng et al., 2023). Subsequently, an operationalization matrix was created to define the variables, categories, and performance levels. Thus, similarly to the procedure followed by Terroba et al. (2021), four categories were established: 1=Very Low; 2=Low; 3=Medium; 4=High. These categories were used to identify the participants' levels in each skill (Table 2).

Table 2

CT-Robot-DST

Dimension	Variable	Categories
Algorithmic Thinking	Counting skill	(1) Does not recognize the cells guiding the path (2) Recognizes the cells but makes many errors when counting (3) Counts the cells but makes some errors (4) Counts the cells correctly
	Logical reasoning (coding of the 6 sequences the robot must perform)	(1) Does not code any of the sequences the robot must perform (2) Codes 1-2 out of 6 sequences correctly (3) Codes 3-4 out of 6 sequences correctly (4) Codes 5-6 out of 6 sequences correctly
	Spatial orientation	(1) Does not know how to move elements in the physical and digital environment (2) Can only move elements forward (3) Can move elements sideways (4) Can move elements in all directions
Generalization and Abstraction	Eye-hand coordination and interaction	(1) Does not recognize or interact with physical and digital elements (2) Recognizes the elements but does not know how to interact with them

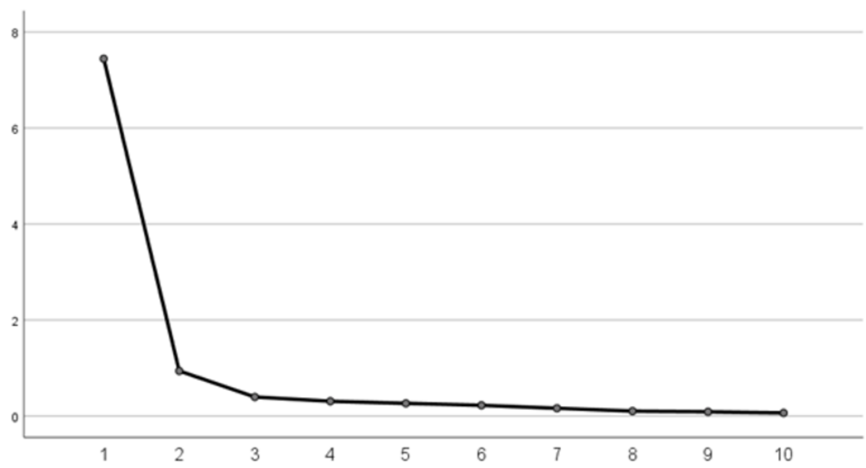
Dimension	Variable	Categories
		(3) Has difficulty interacting with some elements (4) Correct eye-hand coordination and interaction
	Abstraction (identifying the button/action)	(1) Does not identify the buttons to move the robot (2) Only identifies the forward button (3) Identifies the turning buttons (left/right) but makes some errors (4) Identifies all buttons
	Memory activation	(1) Does not remember the story or tasks requested (2) Remembers the story but not the tasks (3) Remembers the story but not the instructions to complete the tasks (4) Remembers the story and how to complete the tasks
Decomposition and Evaluation	Discrimination of laterality	(1) Has not acquired laterality (2) Makes many errors in discriminating left/right (3) Makes occasional errors (4) Has fully acquired laterality
	Moves the robot across the squares of the mat with effectiveness	(1) Moves the robot without criteria (2) Moves the robot and does not notice errors (3) Moves the robot and notices errors (4) Moves the robot, notices errors, and corrects them
	Codes the sequence, engages in the action, and evaluates its accuracy	(1) Does not know how to code the sequence in the robot (2) Codes the robot but does not know how to evaluate its accuracy (3) Codes the robot but requires feedback from an adult to evaluate its accuracy (4) Codes the robot, engages in the action, and evaluates its accuracy
	Engages in the story as a supporting character	(1) Remains indifferent to the story and the challenges presented (2) Focuses on the challenges, ignoring the story (3) Focuses on the challenges to progress in the story with the robot (4) Holds dialogues with the robot co-protagonist to achieve the story's goal

Source: Created by the author.

The instrument was validated through Exploratory Factor Analysis. Bartlett's sphericity test is significant ($p<0.001$) and the Kaiser-Meyer Olkin (KMO) measure of sampling adequacy presents a high value (KMO=0.914). The unweighted least squares (ULS) method was used, and the factors obtained were rotated obliquely using the Oblimin method, as despite having sufficient response categories, their distribution is not normalized according to the Kolmogorov-Smirnov Test (KS<0.001). It was found that 74.5% of the variance is explained by a single factor (Figure 9).

Figure 9

Scree plot



Source: Created by the author.

Referencing the extraction communalities, all items explain a significant portion of the variability of each variable, with values equal to or greater than 0.600. Furthermore, according to the component matrix, all items group around a single factor, making this a unidimensional instrument for measuring CT. Complementarily, the obtained Cronbach's Alpha coefficient is very high (α=0.954), indicating that the scale has a good level of reliability.

The CT-Robot-DST was administered during the intervention through direct observation by the researcher, who recorded the students' behaviors in real time using a previously agreed-upon rubric.

5. Results

5.1. Initial Computational Thinking (CT) Diagnosis and Level Achieved After the Intervention

The data analysis confirms a statistically significant improvement in the students' CT level after the intervention, as seen in the scores achieved both in the skills related to algorithmic thinking and generalization and abstraction. Particularly relevant is the increase in skills for decomposition and evaluation ($\bar{x}$: pre-test=2.17 vs. $\bar{x}$: post-test=3.40; $p < 0.001$) (Table 3).

Table 3

Comparison of scores achieved in the dimensions defining CT

	Pre-test		Post-test				
Activity (A)	$\bar{x}$	DT	$\bar{x}$	DT	R_{xy}	**Z**	**p**
A1. Algorithmic Thinking	3.59	0.888	3.76	0.658	0.817	-2.81	**0.005**
A2. Algorithmic Thinking	3.09	0.834	3.41	0.702	0.803	-5.014	**<0.001**
A3. Algorithmic Thinking	2.89	1.122	3.15	1.044	0.899	-4.200	**<0.001**
A4. Algorithmic Thinking	2.33	1.267	2.70	1.437	0.889	-4.388	**<0.001**
A5. Generalization and Abstraction	3.41	0.816	3.54	0.706	0.895	-2.887	**0.004**
A6. Decomposition and Evaluation	2.17	0.979	3.40	0.814	0.672	-7.343	**<0.001**
TOTAL: COMPUTATIONAL THINKING	2.94	1.070	3.38	0.855	0.875	-5.840	**<0.001**

Source: Self-made.

Post-hoc contrasts show no statistically significant differences related to age or gender. However, it is noteworthy that girls show higher values in the different skills and, therefore, in CT (Table 4).

Table 4

Comparison of CT scores (Pre-test/Post-test) by gender

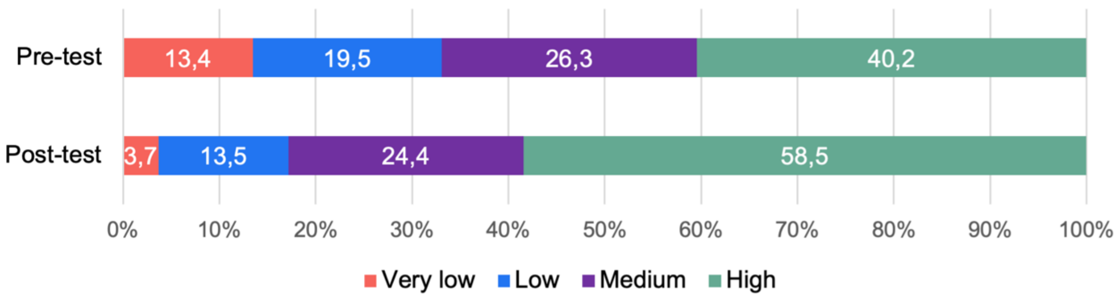
	Pre-test			Post-test		
Activity (A)	**Boy**	**Girl**	**p**	**Boy**	**Girl**	**p**
A1. Algorithmic Thinking	3,54	3,65	0,567	3,67	3,88	0,259
A2. Algorithmic Thinking	3,04	3,15	0,603	3,35	3,50	0,475
A3. Algorithmic Thinking	2,83	2,97	0,660	3,06	3,26	0,492
A4. Algorithmic Thinking	2,31	2,35	0,917	2,63	2,79	0,564
A5. Generalization and Abstraction	3,40	3,44	0,756	3,48	3,62	0,406
A6. Decomposition and Evaluation	2,15	2,21	0,690	3,33	3,50	0,617
TOTAL: COMPUTATIONAL THINKING	2,90	3,00	0,700	3,29	3,50	0,431

Source: Self-made

Based on these results, the overall CT level of the students was calculated, establishing four performance levels: very low: 0.00-0.99; low: 1.00-1.99; medium: 2.00-2.99; high: 3.00-4.00. Figure 10 shows the distribution of students according to the CT level achieved before and after the intervention, with notable increases observed.

Figure 10

Percentage distribution of students according to the CT level achieved in the pre-test/post-test



Source: Self-made

Thus, Table 5 shows that 17.1% maintain their initial CT level after the intervention, while 42.7% increase one or even two levels. On the other hand, 40.2% of students who were already at the highest level before the intervention remain at that level. As for students with Special Educational Needs (SEN), six students from the "very low" level move to the "low" level, one from the "low" level stays in the same level, and two who were at the "high" level remain there (one with ADHD and the other with ASD). Therefore, half of the 12 students with SEN improve their CT with the intervention. However, four of these students (one with ADHD and three with developmental delays) remain in the "very low" or "low" levels.

Table 5

Distribution of subjects by their CT level and increase after the intervention

Level	Pre-test		Post-test		Level maintained		Increase 1 level		Increase 2 levels	
	With SEN	Without SEN	With SEN	Without SEN	With SEN	Without SEN	With SEN	Without SEN	With SEN	Without SEN
	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)	N(%)
Very low	9(11.0)	2(2.4)	3(3.7)	0(0.0)	3(3.7)	0(0.0)	6(7.3)	1(1.2)	0(0.0)	1(1.2)
Low	1(1.2)	15(18.3)	7(8.5)	3(3.7)	2(2.4)	2(2.4)	0(0.0)	12(14.6)	0(0.0)	0(0.0)
Medium	0(0.0)	22(26.3)	0(0.0)	20(24.4)	0(0.0)	7(8.5)	0(0.0)	15(18.3)	0(0.0)	0(0.0)
High	2(2.4)	31(37.8)	2(2.4)	46(56.1)	-	-	-	-	-	-

Source: Self-made

5.2. Effect of the Intervention on the Increase in Computational Thinking (CT)

During the described intervention, which was supported by a playful narrative featuring a robot, the skills intrinsic to the dimensions of CT that the students demonstrated in their executions were measured. These were associated with the progress and achievement of the story's goal, which was led by the turtle. The CT-Robot-DST instrument was used for this purpose, allowing for the evaluation of the skills activated by the subjects, classifying them into four performance levels (Table 6).

Table 6

Descriptive statistics of the levels achieved by the students in the CT skills

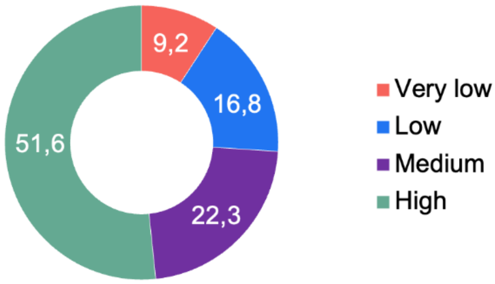
Computational Thinking Skills	Variables	Ver low	Low	Medium	High	x̄	DT
		N(%)	N(%)	N(%)	N(%)		
Algorithmic Thinking	Skill for counting	0(0.0)	6(7.3)	12(14.6)	64(78.0)	3.71	0.598
	Logical reasoning	13(16.0)	15(18.5)	23(28.4)	30(37.0)	2.86	1.093
	Spacial orientation	7(8.5)	19(23.2)	18(22.0)	38(46.3)	3.06	1.023
	Subtotal	-	-	-	-	3.16	1.024
Generalization and Abstraction	Eye-hand coordinarion and interaction	3(3.7)	16(19.5)	24(29.3)	39(47.6)	3.21	0.885
	Abstraction	5(6.1)	13(15.9)	17(20.7)	47(57.3)	3.29	0.949
	Memory activation	11(13.4)	15(18.3)	18(22.0)	38(46.3)	3.01	1.094
	Subtotal	-	-	-	-	3.30	1.002
Descomposition and evaluation	Lateralization discrimination	4(4.9)	11(13.4)	20(24.4)	47(57.3)	3.34	0.892
	Moves the robot across the squares of the mat, verifying its effectiveness	2(2.4)	10(12.2)	22(26.8)	48(58.5)	3.41	0.800
	Codes the sequence, engaging in the action and evaluates its accuacy	13(15.9)	21(25.6)	13(15.9)	35(42.7)	2.85	1.145
	Engages in the story as a secondary character	17(20.7)	12(14.6)	16(19.5)	37(45.1)	2.89	1.197
	Subtotal	-	-	-	-	2.95	1.065
TOTAL: Computational Thinking						**3.22**	**1.006**

Source: Self-made.

The highest scores achieved by the students are recorded in the skill "Generalization and Abstraction" (x̄=3.30) and "Algorithmic Thinking" (x̄=3.16), followed by "Decomposition and Evaluation" (x̄=2.95). On the other hand, the level of computational thinking (CT) obtained by the subjects is medium-high (x̄=3.22) (Figure 11).

Figure 11

Percentage distribution of the sample according to the level of CT demonstrated during the intervention



Source: own elaboration

Subsequent analysis of means according to the age variable does not yield statistically significant differences. However, when comparing the scores achieved by students based on gender, it is found that girls perform better than their male counterparts, although these differences are statistically significant only regarding their ability to decompose and evaluate tasks (x̄: boy=2.71 vs. x̄: girl=3.29; p=0.021). Specifically, they stand out in coding and evaluating the sequence of robot movements required to move it across the mat. They appear more self-critical and more engaged in the action. They also excel in their immersion in the narrative by assuming the role of a secondary character, concerned with achieving the final goal of the challenges, in this case, finding the turtle's home (Table 7).

Table 7

Mean comparison by gender

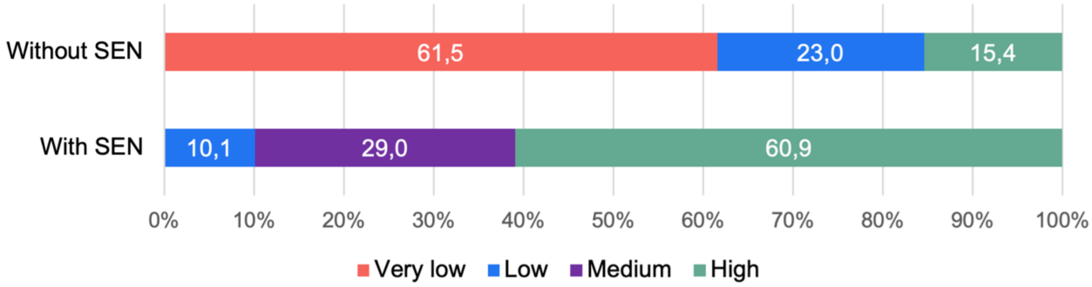
CT Skills	Variables	Boy	Girl	p	d
Algorithmic Thinking	Skill for counting	3.63	3.82	0.312	0.096
	Logical reasoning	2.89	2.82	0.653	0.057
	Spacial orientation	3.13	2.97	0.303	0.126
	Subtotal	3.29	3.06	0.514	0.079
Generalization and Abstraction	Eye-hand coordinarion and interaction	3.25	3.15	0.361	0.111
	Abstraction	3.23	3.38	0.796	0.031
	Memory activation	2.94	3.12	0.681	0.051
	Subtotal	3.23	3.41	0.554	0.067
Descomposition and evaluation	Lateralization discrimination	3.42	3.24	0.092	0.196
	Moves the robot across the squares of the mat, verifying its effectiveness	3.31	3.56	0.243	0.135
	Codes the sequence, engaging in the action and evaluates its accuacy	2.58	3.24	**0.010**	0.317
	Engages in the story as a secondary character	2.58	3.32	**0.008**	0.327
	Subtotal	2.71	3.29	**0.021**	0.287
TOTAL: PENSAMIENTO COMPUTACIONAL		3.15	3.32	0.552	0.071

Source: Self-made

As expected, given the difficulties of students with SEN, when comparing the mean scores achieved in computational thinking (CT) with those of the rest of their classmates, significant differences are found (x̄: with SEN=1.69 vs. x̄: without SEN=3.51; $p<0.001$). In Figure 12, it is observed that students with greater difficulties are at the lower levels.

Figure 12

Percentage distribution of the sample with and without SEN according to their CT level

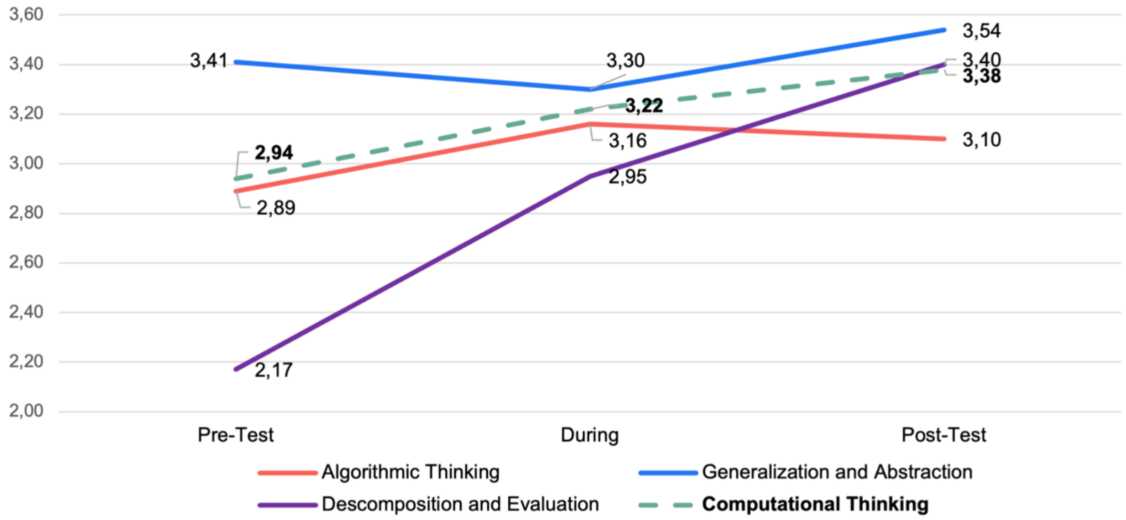


Source: own elaboration

The evolution of CT after the intervention is positive, as evidenced by comparing the means achieved in the Computational Thinking construct by the students, showing an increase of 0.44. In particular, there is a notable increase of 1.23 points in the skill "Decomposition and Evaluation" (Figure 13).

Figure 13

Evolution of the CT means and its skills before, during, and after the intervention



Source: own elaboration

Finally, to determine the extent to which the skills activated during the intervention influence the level of CT reached in the post-test, a multiple linear regression analysis was conducted, confirming that all of them have an impact on the students' CT level (Table 8).

Table 8

Multiple regression model between the intrinsic CT skills activated during the intervention

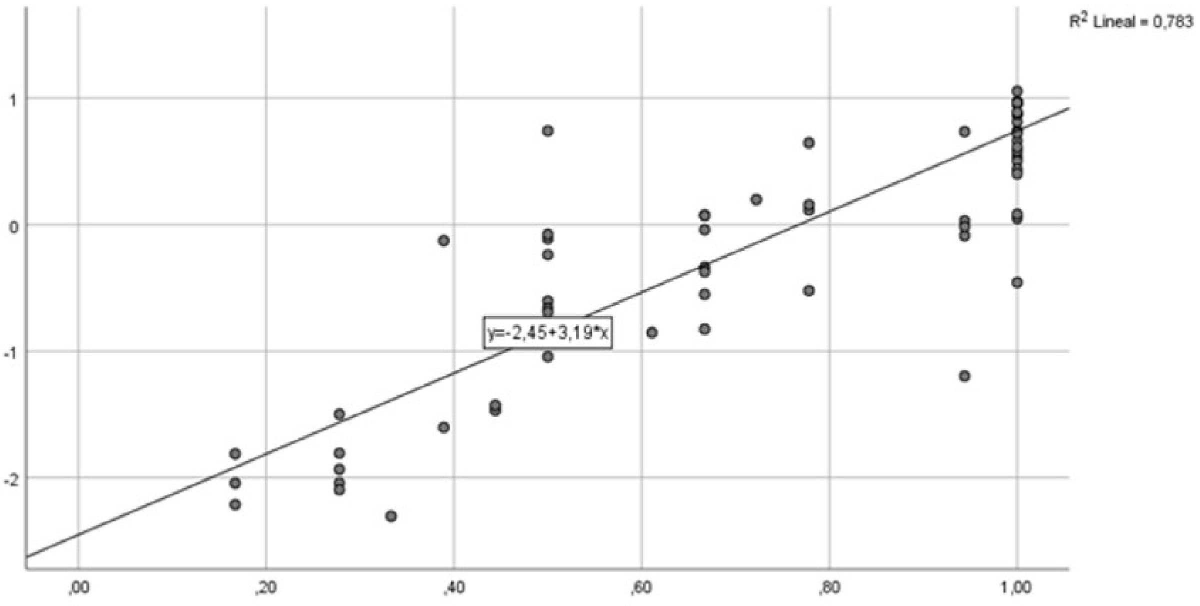
Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Desv. Error	Beta		
(Constant)	-0.120	0.119	-	-1.009	0.317
Counting ability	0.042	0.051	0.089	0.820	0.415
Logical reasoning	0.055	0.039	0.216	1.402	0.165
Spatial orientation	0.009	0.045	0.033	0.197	0.844
Oculo-manual coordination and interaction	0.026	0.054	0.083	0.484	0.630
Abstraction	-0.006	0.042	-0.020	-0.138	0.890
Memory activation	0.124	0.036	0.490	3.464	0.001
Laterality discrimination	-0.022	0.039	-0.072	-0.575	0.567
Moves the robot across the squares of the mat, verifying its effectiveness	0.051	0.036	0.146	1.435	0.156
Encodes the sequence, engaging in the action, and evaluates its accuracy	-0.016	0.027	-0.066	-0.599	0.551
Gets involved in the story as a supporting character	0.018	0.019	0.080	0.989	0.326

Source: own elaboration

It can be observed that the set of skills activated by the intervention explains a high percentage of computational thinking, as it predicts 78.3% of the subjects' results (R2=0.783). Specifically, memory activation—associated with recalling the story and the tasks requested—is statistically significant. The regression line shows the relationship between the values obtained by the subjects in the analyzed skills (independent variables on the x-axis) and their connection with computational thinking (dependent variable on the y-axis) (Figure 14).

Figure 14

Scatter plot and multiple linear regression analysis



Source: Own elaboration

6. Discussion and Conclusions

In light of the results, it is evident that the intervention—supported by the narrative of the search for a home for the turtle, which required robot coding and the completion of digital, physical, and augmented activities—contributed to the increase in computational thinking (CT) among Early Childhood Education students. This innovative practice has yielded positive results, similar to the experiences conducted by Berson et al. (2023) and Terroba et al. (2021), who also advocated for integrating play within interventions using robotics at this educational level to stimulate algorithmic thinking, as well as skills in generalization, abstraction, decomposition, and evaluation, all of which are part of CT.

The intervention contributed to the activation of various skills associated with CT. On one hand, students were asked to count the squares the robot needed to advance through, sequence tasks, orient themselves spatially on the mat and within the digital environment (tablet) to perform the indicated activities, and associate marine characters with their habitats, rotating 3D animals to discern their qualities, among other tasks. The experience also required eye-hand coordination and interaction, both with physical elements like the mat, the robot, or the turtle, and with immersive activities designed through an app. Without a doubt, the use of micro-stories embedded in immersive scenarios supported by augmented reality (AR) contributes to the development of students' spatial orientation by immersing them in digital fictional environments. Additionally, the interaction with physical and augmented elements creates multisensory experiences that reduce the cognitive load associated with sequencing and problem-solving, as noted by Işik et al. (2024).

During the intervention, students recorded lower values in the abstraction skill compared to pre-test and post-test scores, due to the novelty and complexity of the proposed activity, as they had to code the robot's movements by associating each button with the corresponding action to achieve its goal. Furthermore, performing the sequence of activities integrated into the story required activating memory to recall the instructions. Regarding the CT skills enhanced after the playful experience, the improvement in the “Decomposition and Evaluation” skill stands out, which may be attributed to the appeal of the story underlying the activity requested from students: finding the shortest path to the turtle's birthday cake, an activity that is rewarding for them. This skill is closely related to the segmentation of the robot's coding activities to move forward and the verification of its adequacy to the task (“I'm behind!”, “I overshot it, I almost left the path,” etc.), as well as the ability to repeat actions (“I have to do it again...,” “Can I try again?”, etc.).

It should be emphasized that, although the participating students had not previously used educational robotics, all benefited from the intervention, regardless of gender and age. The same is true for students with Special Educational Needs (SEN), although only half of them showed an increase in their CT level, while the rest, with greater difficulties, remained at their initial values. Without a doubt, integrating augmented digital micro-stories into playful scenarios where a robot is the protagonist is an innovative—and effective—proposal for stimulating CT. Furthermore, the integration of robotic coding as a means to contribute to the happy ending of a story allows students to be introduced to programming and develop other associated skills, such as spatial orientation, laterality, counting, eye-hand coordination, logical reasoning, etc. Advancing the robot through a playful and immersive scenario that invites students to overcome and solve various tasks integrated into a story increases their CT while also enhancing their emotional involvement with the proposed activities.

The design of the intervention is based on a constructivist view of learning, where students build knowledge through meaningful and contextualized experiences, in this case within micro-stories. At the same time, the experience is framed within a situated learning approach by linking the activities to the students' immediate environment—the marine environment—thus promoting knowledge transfer. Moreover, the STEAM approach is present by integrating technology, narrative, and CT, allowing for the joint promotion of areas such as Science, Technology, Engineering, Art, and Mathematics. All of this allows the results to be interpreted not only in terms of their practical effectiveness but also from a solid conceptual foundation, which strengthens the validity of the conclusions reached. Therefore, the findings of this research are grounded in established pedagogical principles that provide theoretical robustness to the proposal.

As limitations of the study, it should be noted that the results refer to a specific school context with students aged 4 to 6 years. Possible biases must also be acknowledged due to the non-random selection of the sample and the absence of a control group. Additionally, it would be interesting to expand the sample in the future and/or conduct the intervention with students of other ages. Similarly, the narrative could be adapted to centers of interest relevant to the participants' context, integrating other applications and activities that require activating skills associated with CT. Furthermore, the designed instruments and the narrative itself could be translated into other languages, facilitating their replication in other contexts.

Regarding future research lines, it would be appropriate to conduct comparisons with other methodological approaches to activate CT—both with and without the use of digital devices—to explore the application of micro-stories in different curricular areas and to carry out longitudinal studies to assess the sustainability of learning over time.

Author contributions
Conceptualization, M. Esther Del-Moral-Pérez, Nerea López-Bouzas; data curation, Jonathan Castañeda-Fernández; formal analysis, M. Esther Del-Moral-Pérez, Nerea López-Bouzas, and Jonathan Castañeda-Fernández; funding acquisition, M. Esther Del-Moral-Pérez; investigation, M. Esther Del-Moral-Pérez, Nerea López-Bouzas, and Jonathan Castañeda-Fernández; methodology, M. Esther Del-Moral-Pérez, Nerea López-Bouzas, and Jonathan Castañeda-Fernández; project administration, M. Esther Del-Moral-Pérez; resources, Nerea López-Bouzas; software, Nerea López-Bouzas; supervision, M. Esther Del-Moral-Pérez; validation, Jonathan Castañeda-Fernández; visualization, Nerea López-Bouzas; writing—original draft preparation, M. Esther Del-Moral-Pérez, Nerea López-Bouzas, and Jonathan Castañeda-Fernández; writing—review and editing, M. Esther Del-Moral-Pérez, Nerea López-Bouzas, and Jonathan Castañeda-Fernández

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Data Availability Statement
The data set used in this study is available at reasonable request to the corresponding author

Ethics approval
The intervention was carried out after obtaining permission from the Ethics Committee of the University of Oviedo (37_RRI_2024). Additionally, the purpose and procedures were explained to the teaching staff and families (see explanatory document at: https://cutt.ly/geue42E1). The processing, communication, and transfer of data were conducted in accordance with Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (GDPR), as well as Organic Law 3/2018 of 5 December on the Protection of Personal Data and guarantee of digital rights (LOPDGDD). The research team maintains custody of the anonymized data to ensure confidentiality.

Consent for publication
The author has consented to the publication of the results obtained by means of the corresponding consent forms.

Conflicts of interest
The author declares that they have no conflict of interest

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