Coding with colors: Children's errors committed while programming Robotito for the first time

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Abstract. Robotito is an educational robot developed in Uruguay to stimulate the development of computational thinking in young children. We conducted an exploratory study to detect difficulties that emerge during the first approximation of preschool children to Robotito (Study 1). Based on the lessons learned, we implemented improvements in robot design and the structure of the introductory activities with Robotito and conducted a pilot study (Study 2) to evaluate them. This poster presents observed programming errors, lessons learned, and future works.

Keywords: Child-robot interaction · Preschoolers · Educational robotics.

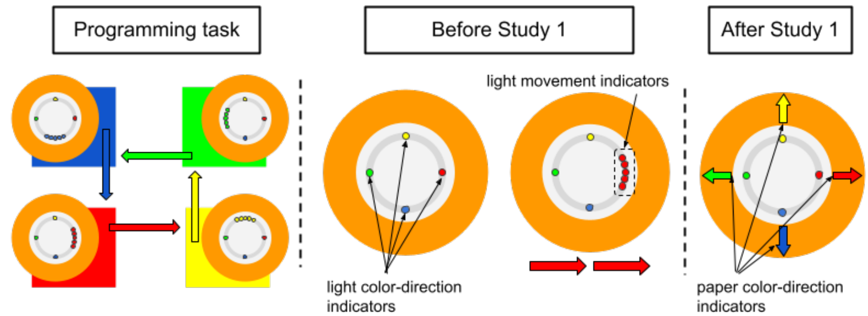
1 Introduction

Robotito is an educational robot developed at the Facultad de Ingeniería of Universidad de la República, Uruguay, with the goal of introducing young children to programming and fostering their computational thinking (CT) skills [3, 1]. The robot's programming is based on the placement of color cards on the floor, with each color representing a specific movement: yellow for forward[5], red for left, blue for backward, green for right, and purple for spin. Unlike other commercial robots, Robotito is omnidirectional, meaning it can move in any direction without turning. To aid children in programming and understanding the robot's movements, a LED ring on the top of the robot indicates the associated color for each direction and shows the current direction of movement (see Figure 1). These light indicators serve as the only color-direction reference for selecting the appropriate color card to move the robot in a specific direction.

In order to enhance the interaction between children and Robotito, as well as facilitate the development of CT activities, we conducted two exploratory studies in 2022 to identify potential difficulties that may arise during children's interaction with the robot. The purpose of these studies was to develop effective strategies to mitigate these challenges. In this poster, we present the outcomes and findings from these studies.

[5] Robotito has no face or front, so the relation to directions "forward", "backward", "left" and "right" are used only to distinguish its four predefined directions.

Fig. 1. Programming task and Robotito's direction indicators before and after Study 1.



2 Methodology

We conducted two field studies involving a total of ten 5-6-year-old children (Study 1 with 4 girls and 4 boys, Study 2 with 2 boys). The initial exploratory study aimed to identify errors made by children during robot programming and opportunities for improving the robot's design and presentation to children. Subsequently, we conducted a pilot study (Study 2) to evaluate improvements in the presentation format in individual instances.

For Study 1, we collaborated with a public kindergarten in Montevideo, Uruguay, where eight children participated. The classroom teacher divided them into four pairs. The first child in each pair interacted with the robot, learned about the color codes, and engaged in solving a programming task. The objective was to program the robot to follow a square-shaped route ("draw a square"), accomplished by placing four color codes on the floor (see Figure 1). Afterward, the second child joined the activity and received instructions from the first child through peer tutoring (peer tutoring [2]) on using the robot and solving the same programming task.

In Study 2, we individually explained the programming process to children using color codes on the floor, following points 1 to 6 from a structured presentation developed based on the insights from the first study (see the 3 section).

Both sessions were video recorded and analyzed by three researchers, focusing on the common errors committed by the children (Study 1 and 2) and the explanations given by the child tutors during peer tutoring (Study 1).

The study protocol received approval from the ethics board of the principal institution, and we obtained informed consent from the parents or caregivers of the participating children, ensuring diligence in ethical considerations.

3 Results

In Study 1, we identified various aspects to improve related to the observed programming errors, peer tutoring, activity structure, and robot design.

Programming errors We identified five types of errors that the children committed while programming the robot. The main cause of programming errors was a lack of understanding of the light-direction relationship that is essential to program the robot. Three error categories reflected it. **"Memorized color-direction relationship"** (MCD, 2/10 children) was used to tag situations in which the children associated a color with one specific direction in the space (for example, green - child's forward) and ignored the fact that the direction associated with the color will change in reference to the child's position after rotating the robot.

We tagged as **"repeated the lights distribution"** (RLD, 3/10) events in which children tried to solve the "draw a square" task by placing the cards mimicking the same distribution as the lights on the robot.

Additionally, we observed that the children frequently wrongly predicted the direction the robot would take after sensing a specific color card or pointed wrong color when asked, "what color should we use to make Robotito move THAT direction" and codified these errors as **"wrong color/direction prediction"** (WRP, 6/10). Some children did not understand the "draw a square" task, and we codified errors related to this fact as **"no task comprehension"** (NTC, 2/10).

"Wrong coding card position" (WCP, 6/10) was used for events in which the children did not correctly predict the robot's movement after sensing a specific color and put the next card aside from the robot's trajectory.

Peer Tutoring Half of the tutors memorized coding card positions and explained **where** to put each color card to "draw a square," not **how** the robot works. In fact, none of the tutors explained the relationship between the light indicators on the robot and the direction of its movements. Two tutors mentioned the lights during their explanation, although they focused on the fact that there are more color lights when the robot detects a color card and did not connect color lights to directions. Two of the four tutors **rotated the robot** to explain the color-direction relationship.

Lessons Learned We proposed improvements related to robot design and activity structure based on the observed errors and peer tutoring instances. We observed that **the color lights** on the top of the robot **are not clear indicators of the color-direction relationship**. Children committed various errors (MCD, RLD, WRP) due to their lack of understanding of the relation between the color-direction indicators and the robot movements. Most participants had difficulties in predicting the robot direction or choosing an appropriate color in simple programming tasks. None of the child tutors mentioned the colors to explain the programming rules of the robot. We concluded that four colorful lights were not enough to transmit the idea of direction and opted to add paper arrows in corresponding colors on top of the robot, next to light indicators (see Figure 1). As there were multiple occurrences of "wrong color/direction prediction" in the simple tasks, in addition to adding paper arrows, we decided to extend the robot's presentation and explanation. We opted for **more guided instances** where the child has to point to colors, directions or rotate the robot. The **rotation of the robot** was identified as a crucial point in the understanding of color-direction relationship and we believe that it contributed to reducing MCD and WRP errors (none MCD and only one WRP in Study 2). Children tutors that understood the robot's programming rules rotated the robot to explain that with a particular color, the robot can go "this way" or, when turning it, can go "that way."

We observed that the "drawing a square" task was too complex for an introductory activity, and we added **intermediate tasks** with increasing difficulty (go in X direction, use two color cards to make it move in an L-shaped path, use three cards to move in U-shaped route) between robot presentation and "drawing a square." Also, the use of a geometric concept may make it difficult for children to understand the expected robot's path. We added **visual support** (the researcher drawing with the finger the square on the mat) to the oral explanation to make the task easier to understand. To avoid WCP errors, we incorporated an **explanation of the position of the color sensor** used for detecting the color cards.

The result of our observations was a structured introduction to Robotito with the following points that should be covered:

1. Introduction to the color-direction relation using color arrows on the robot.
2. Demonstration of the color sensor and color cards.
3. Demonstration of color-direction examples using Robotito and color cards.
4. Guided tasks in which the child selects the color to move Robotito forward with multiple instances of rotating the robot ("Which color should we use to make the robot move forward if the robot is in this position?").
5. Guided tasks in which the color and direction are given the child selects the robot orientation ("Robotito should go forward with yellow, how should we rotate Robotito?").
6. Programming L-shaped paths.
7. Programming U-shaped path.
8. Programming square-shaped path.

4 Conclusion and Future work

The first exploratory study allowed us to identify improvements and develop age-appropriate and robot-specific introduction. Although in Study 2, the number of error types was reduced from five to two, participants still committed WCP errors. We observed those errors in real-time debugging instances (the robot is moving, and the child tries to correct the program before the robot reaches the next card). These kinds of instances, with robot moving and the child placing the next card, were not covered in the introduction, and we consider that adding them will help children to better predict the robot's trajectory and put the coding card in the correct location.

Our study highlights the significance of understanding children's common errors and challenges during programming activities, as it can significantly impact the design of robots and related activities, ultimately facilitating children's learning process. Our next phase involves collaborating with teachers to adapt the complete introductory activity to fit the classroom environment and subsequently evaluate its effectiveness in a classroom setting.

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