Robotito Test in Practice: A Classroom Evaluation

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As Computational Thinking (CT) becomes more prevalent in school curricula, it has reached young children, with growing interest in incorporating CT for children in preschool and kindergarten. As more researchers design systems and curricula to teach CT for this age group, there is a need for assessments to better evaluate and compare approaches to teach CT. In this work-in-progress we present activities with 5-6-year-old children from two classrooms. In these classrooms, children participated in educational robotics (ER) activities using a robot that can be programmed through cards placed on the floor for the robot to read as it moves. We developed a test aimed at evaluating children's ability to program the robot, which we administered after the activities. We discuss lessons learned through the administration of the test, both about the ER activities and the test.

CCS Concepts: • **Human-centered computing** → **User interface programming**; **Empirical studies in ubiquitous and mobile computing**; • **Social and professional topics** → *Computational thinking*.

Additional Key Words and Phrases: Computational thinking, Educational robotics, Educators

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1 INTRODUCTION

Computational thinking (CT) is defined as the process of formulating problems and designing solutions in a way that enables a computer—whether human or machine—to execute them efficiently [8]. Recognized as a fundamental skill for active participation in the digital age [15], CT has been increasingly integrated into educational curricula worldwide [4, 15].

Research highlights the importance of introducing CT at an early age, with empirical studies demonstrating the feasibility of teaching CT concepts to preschool children [7, 10, 11, 14]. Many of these studies leverage educational robotics as an effective approach, as robots offer a tangible and interactive medium for engaging young learners with abstract computational concepts.

Robotito is an open-source, open-hardware educational robot designed to introduce CT to young children [19] (see Section 2 for further details). Prior studies suggest that Robotito effectively promotes CT development in preschoolers [6] and supports collaborative learning, allowing small groups of children to work together using a single robot [2].

This work presents the findings of an educational robotics (ER) intervention using Robotito, aimed at fostering CT development in level 5 kindergarten children. We were interested in evaluating children's understanding of Robotito related concepts, to assess the effectiveness of our intervention and refine Robotito's curriculum. To achieve this,

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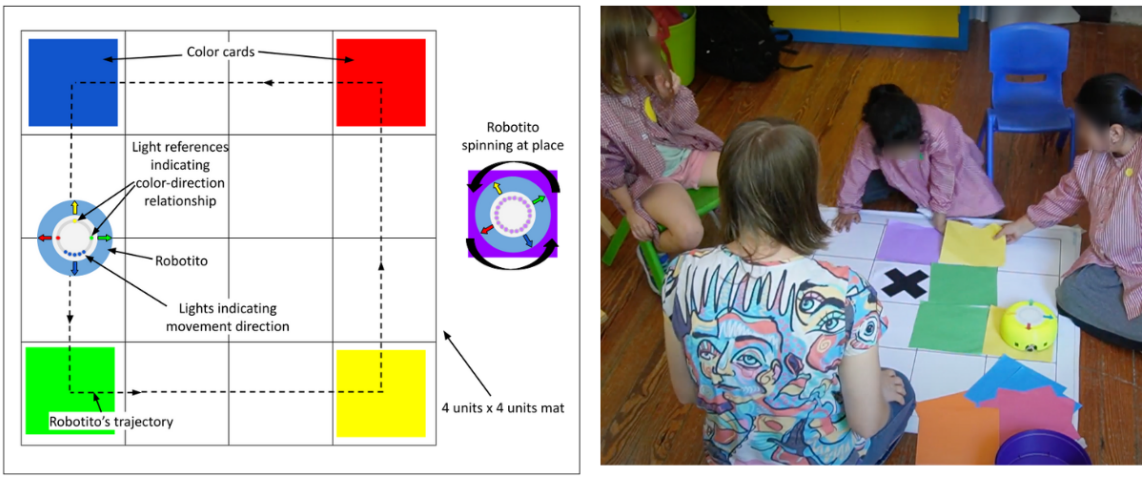

Fig. 1. Left: A schema of Robotito's response to color cards. The robot moves forward with yellow, left with red, backward with blue and right with green. Purple makes it spin. Right: An example of children solving a programming task.

we developed a custom assessment tool, the Robotito Test. Designed as a paper-based test, it provides a scalable and easy-to-administer evaluation method, unlike assessments that rely on direct interaction with the robot. In this work-in-progress, we present the test, its results, and lessons learned from developing and administering it. We hope that our experience can be useful to other researchers working on assessments of similar systems.

2 METHODOLOGY

The study was conducted with two preschool classes, implementing eight ER sessions, followed by the administration of the Robotito Test, a custom assessment designed to evaluate children's understanding of the concepts introduced.

We worked with 36 preschoolers (two classrooms; A1 with 17 students and A2 with 19 students) from level 5 (5 to 6 years old) at a public school in Montevideo, Uruguay.

Robotito is an educational robot developed at Universidad de la República (Uruguay), designed to teach children CT concepts such as trajectory planning, sequencing, decomposition, and debugging.

On its underside, it has a sensor that enables it to detect color cards placed on the floor. It responds to these cards by changing its movement direction according to the detected color: yellow makes it move forward[1], red to the left, blue makes it move backward, green to the right, while purple makes it spin (see Figure 1).

In this study, two additional color cards were introduced: orange, for conditional sound reproduction, and pink, to familiarize children with the concept of modularization. The orange card toggles whether Robotito plays a sound when reading any other card. After detecting the pink card, Robotito moves one step forward (yellow direction), then one step right (green direction), then stops moving. During the execution of this "pink step," the robot ignores all other color cards.

We conducted eight ER activities with Robotito between November and December of 2023 (see Table 1). The activities were designed taking into account lessons learned from two exploratory studies [3], new capabilities of the robot

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

(conditional sound reproduction and “pink step"), and ideas from a preschool teacher who worked with Robotito in her classroom. A detailed description of all activities can be found in Appendix A.

2.1 Data collection and analysis

Robotito Test was developed to assess children’s understanding of the concepts that we addressed in the ER activities. All the tasks represent on paper a typical activity setting (Robotito, a 4×4 units grid, and color cards). See Appendix B to visualize the test.

In the first task, children have to choose the colors of two coding cards to guide the robot to the purple card. The route and cards’ locations are predetermined, requiring only the selection of cards’ colors. This task assesses whether children understood the color-direction relationship and can deduce it from a particular robot’s orientation to solve a specific sequencing task.

The second task entails designing a sequence of movements for the robot to reach the purple card while defining both the location and color of the coding cards.

In the third task, children’s comprehension of conditional sound reproduction is evaluated. Here, the U-shaped sequence of the robot’s movements is predetermined, with corresponding cards already in place (see Appendix B). Children are tasked with positioning orange cards to activate or deactivate Robotito’s sound reproduction at two specific points along its route.

The fourth task evaluates the correct usage of the pink card. With the robot initiating its movements on the pink card and aiming to reach the purple card, children are asked to place the missing cards to complete the programming sequence.

We provided the children with four color cards (yellow, red, green, blue) to solve tasks 2 and 4, and with two orange cards to solve task 3. Each task was evaluated as correctly solved (1 point) or incorrectly solved (0 points) without partial credit. Administration was conducted by a single researcher, who could scaffold children with questions like:

- “Can you show me with your finger how the robot will move?” (Task 2 and 4)
- “How does the robot move with the pink card?” (Task 4)

and explain issues that were different between the on-paper robotic task and the real robot acting:

- “It is ok to cover the robot with a color card, it’s the same as placing it below the robot.” (Task 2)
- “You can not cover printed color cards with the orange card.” (Task 3)

These measures aimed to enhance qualitative analysis by providing insight into children’s reasoning and comprehension, and ensure that the children understood the on-paper programming setting.

We video recorded all the activities and the Robotito Test administration to enrich our analysis with qualitative data.

3 RESULTS

We conducted a quantitative analysis of the scores and a qualitative analysis of the videos from the test administration process.

3.1 Quantitative

All the children correctly solved task 1 (choosing colors of the coding cards). Task 2, that required both choosing the color and the place, was correctly solved by 78% of children. The third task (conditional sound reproduction) was solved by 56% of children, and the last task (the correct usage of the pink card) by 61%.

Overall, 36.1% of the children solved all tasks, 33.3% solved 3 of 4 tasks, 19.4% solved 2 tasks, and 11.1% solved only the first task.

3.2 Qualitative

We present general observations along with task-specific ones.

3.2.1 General Observations. SIMULATION. Overall, children did not rely on simulating Robotito's trajectory with their finger to determine the color and placement of the coding cards. However, in certain instances, simulating the path helped them detect errors or determine the appropriate placement for the next color card.

CARD POSITION IN THE GRID. During tasks 2 and 4, some children correctly selected the colors of the cards but struggled with positioning them on the grid. For instance, they placed the second card too close to the first one, causing the robot to change direction too soon. Alternatively, they positioned the card next to the robot's trajectory rather than directly within it.

AMOUNT OF CODING CARDS. Some children wanted to create trajectories that required more than the four color cards initially provided. This occurred when they aimed to create longer, more challenging routes or used "redundant cards," placing two cards of the same color next to each other, even though the second card was unnecessary as it did not alter the robot's movement direction.

MOVING ROBOT IN SPACE. Some children struggled to understand how to use the color cards to move the robot in space. Two children placed the color cards adjacent to each other without considering the colors' meanings, effectively creating "a path of color tiles" rather than using the colors to indicate directions. In some instances, children believed the robot could move diagonally, although this movement is not supported by the robot. Additionally, when asked to demonstrate the robot's movement with their finger, some children indicated that the robot would change direction in locations where no color cards were present.

3.2.2 Task 2 - Selecting Placement and Card Color. COVERING ROBOTITO. In some cases, task 2 caused confusion among children regarding whether it was correct to cover Robotito's image with a color card. To complete the task, children needed to select a color card to initiate the robot's movements, placing it where the robot was drawn. Some children noted that it was impossible to put the color card beneath the robot and asked questions like, "It [the color card] goes above, or what?" Covering the robot with the first color card caused the children to lift it to check the color arrows on the robot and complete the task.

3.2.3 Task 3 - Toggling Sound. This task caused different kinds of confusion and led to unexpected solutions.

COVERING COLOR CARDS. Many children tended to place the orange cards on top of the color cards that coded the U-shaped route. In these situations, the evaluator had to indicate that the color cards should not be covered.

IMPRECISE INSTRUCTIONS. In this task the children were asked "Where should we place the orange color cards so that Robotito makes sounds near the sun and is silent near the moon?" (see Appendix B to visualize the task.) We observed that some children were unsure about what "near the sun/moon" meant in the context of the task. The idea behind the task was to turn on sound mode before the red card (the card closest to the sun) and turn it off before the blue card (the card closest to the moon). However, some children placed the orange cards after these cards, interpreting "near to" more broadly than we intended.

ORANGE CARD FUNCTION. Not all the children understood how the orange card changes Robotito's behavior. Some thought it would change the robot's movement direction, while others believed that the robot would only reproduce

sounds when it passes over the card, using it to "make sounds" rather than to activate and deactivate sound mode. In these cases, children placed only one card close to the sun to "make sounds near the sun." One child thought that to deactivate sound mode, the orange card should be removed after the robot passed over it and made sounds.

INCORRECT PLACE. Some children tended to place both orange cards together between the color cards. They placed them in the first part of the U-shaped route (between the yellow and red card), in the bottom part (between the red and blue card), or even in the top part of the grid (between the yellow and the purple card), which was not part of the robot's route. One child placed the orange card outside the grid and used it to cover the drawing of the sun.

3.2.4 Task 4 - Understanding Compound Command. ALTERNATIVE CARDS. Some children ignored the fact that the robot should start on the pink card and instead tried to build alternative paths. These paths would not be executed by the robot as they started with color cards placed next to the robot, but not in its way.

MOVEMENT SIMULATION. Many children simulated the "pink step" (moving one step in the yellow direction, then one step in the green direction) to decide where to put the next color card. In some cases, they did not place the next card in the square where the "pink step" ended but instead placed it in the following square.

4 DISCUSSION AND CONCLUSION

The Robotito Test results indicated that all the children understood the **color-direction relationship** essential for comprehending the robot's behavior, with more than half of the children correctly solving each task. The children were able to plan trajectories for the robot, divide the route into smaller parts, and translate it into sequences of color cards. These observations suggest that the intervention was successful, but we consider that more activities should be dedicated to reinforce Robotito's response to color cards. Although all the children appeared to understand the rules that govern the robot's behaviors (task 1 was completed by all of the children), we identified several issues related to **misunderstanding the robot's capabilities** (e.g., moving diagonally, or changing direction without color cards). We hope that more instances of robot programming help to overcome these issues.

Test results indicated that task 3 was the most challenging for the children. Difficulties arose due to unclear instructions, a tendency to cover the color cards or place both orange cards together, and a misunderstanding of the orange card's function. We consider that more curricular units dedicated to **conditional sound reproduction** will help to understand the meaning of the orange card.

Although many studies involving physical robots assess children's programming knowledge using paper-based tasks—such as KIBO's Solve-Its [5, 12, 16–18] or paper-based evaluations of Bee-Bot programming [1, 9], our observations revealed challenges associated with the **on-paper nature of our test**. For example, children occasionally disregarded printed cards, and covering the robot's printed image with a paper card led to confusion. These findings suggest that the paper-based evaluation introduced errors that were not present when interacting with the physical robot. However, administering tests using the physical robot poses logistical challenges, as it may not enable multiple children to participate in an evaluation at the same time in a classroom setting.

As a potential alternative, we consider the **Robotito simulator** a promising option that balances ease of administration while addressing some limitations of paper-based assessments. The simulator was already integrated into the ER curriculum (see Appendix A) and children had no difficulty using it. The simulator prevents the robot from being covered by programming cards, and since all cards are digital, there is no mixing of printed and physical cards, reducing the likelihood of errors due to card placement or misinterpretation. Future studies should explore the feasibility of

using a simulator as an evaluation tool. Positive outcomes could suggest similar simulator-based evaluations for other ER systems.

In some cases **simulating the robot's path with the finger** helped children detect programming errors or determine the appropriate placement for the next color card. In particular, during task 4, children frequently used their fingers to define where the robot would stop after executing the "pink step" and placed the following card there. Embodied actions aimed at simulating Robotito's acting, incorporated as a final step of the on-paper programming task, could help children to validate and debug their answers.

Designing Robotito's trajectory, whether using the physical robot or a paper-based representation, requires **spatial reasoning skills**, as children must predict the robot's movement within a two-dimensional space. During our observations, we noted that some children, despite selecting the correct color card, placed it incorrectly, often positioning it adjacent to the intended trajectory rather than directly within it. Since our intervention focused on CT rather than spatial reasoning, we propose the development of additional coding cards for Robotito that enable sequencing tasks without imposing a cognitive load related to trajectory prediction. Specifically, we envision coding cards that trigger actions such as sound effects, light activation/deactivation, or rotational movements. These would allow children to program sequences of actions independently of spatial navigation, facilitating engagement with CT concepts without the additional challenge of trajectory planning.

Improved versions of the Robotito Test should enable us to better evaluate and enhance Robotito instruction. At the same time, we have plans to compare children's performance in Robotito Test with their performance in generic CT tests designed for their age group [13, 20], to better understand the mapping of Robotito concepts to higher-level CT and to assess the level of agreement across these tests.

4.1 Conclusion

The results of Robotito Test indicate that the children successfully planned robot trajectories, segmented the route into smaller steps, and translated these steps into sequences of color cards. These observations indicate that the intervention was effective. However, we recommend incorporating additional activities to further reinforce children's understanding of Robotito's responses to different color cards, especially to the orange card that activates/deactivates sound reproduction.

We also believe that conducting the evaluation on paper may have caused unnecessary confusion. For example, some children covered or ignored printed color cards, a behavior never observed with the physical coding cards. Additionally, in Task 2, placing a color card over the printed Robotito image appeared to cause confusion.

To address these challenges, future evaluations could consider using the Robotito simulator as an assessment tool. The simulator may address issues associated with paper-based tasks while maintaining ease of administration, potentially providing a more accurate evaluation tool. Additionally, the role of embodied actions and sequencing tasks that do not require spatial skills should be further explored in future studies.

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A ACTIVITIES

Activity #1. Total time: 40 minutes. We asked the children to reflect on what the robots are and discussed with them the ideas. Each child explored Robotito (robot turned off) and we talked about what they observed (its parts, materials). We turned on Robotito and thought about how to control it. We explored how it moves with yellow, red, green and blue color cards and fixed the color paper arrows on the top of the robot to indicate the directions in which the robot moves after sensing a specific color.

Activity	Date, class (nr of children)	Modality of work	Main goal of the session
#1	06.11.23 A1 (14) 06.11.23 A2 (18)	Whole class together.	To introduce Robotito and how it moves with yellow, red, green and blue color cards.
#2	10.11.23 A1 (16) 10.11.23 A2 (18)	The class splitted in two groups.	To reinforce how the robot responds to color cards through an embodied experience. To observe that the color cards should be placed in the robot's trajectory.
#3	20.11.23 A1 (16) 17.11.23 A2 (18)	The class splitted in two groups.	To understand that directing the robot depends on the color of the coding card and the robot's rotation. To reinforce that the color cards should be placed in the robot's trajectory.
#4	22.11.23 A1 (16) 20.11.23 A2 (19)	Whole class together.	To reinforce how the robot responds to color cards through more individual interaction with Robotito's simulator. To practice route planning, sequencing and sequence decomposition.
#5	24.11.23 A1 (15) 24.11.23 A2 (15)	The class splitted in two groups.	To plan Robotito's trajectories, select the corresponding color cards, and place it in space. To introduce conditional music reproduction using the orange card.
#6	27.11.23 A1 (14) 24.11.23 A2 (16)	The class splitted into small groups.	To practice coding Robotito's routes and reinforce how it responds to the orange card.
#7	29.11.23 A1 (14) 29.11.23 A2 (17)	The class splitted in two groups.	To introduce a pink card that makes the robot execute a prerecorded sequence of movements and stop.
#8	04.12.23 A1 (14) 04.12.23 A2 (18)	The class splitted into small groups.	To reinforce how the robot responds to the pink card and practice combining it with the other coding cards.

Table 1. Summary of ER sessions.

Activity #2. Total time: 60 minutes. First, we reviewed the components of Robotito and its responses to color cards. Next, we explained that the activity would be conducted in two groups: one group would draw, while the other would role-play as Robotito, with roles switching afterward. For the drawing activity we provided three Robotitos: two normal robots and one without the shell to observe the inner parts of the robot.

The group that was playing to be Robotito was divided in pairs. One pair acted in front of the rest of the children that observed from their chairs. One child from each pair was acting as Robotito, the other as a programmer that places the color cards on the floor to move the robot. The idea was to direct the robot without hitting the furniture or the classmates. After a while of playing, the children switched the roles. After one pair went through playing robot and programmer, the next pair was called to perform in front of the others.

Activity #3. Total time: 60 minutes. We discussed the drawings done in the previous session. We splitted the group in two. Each group worked with one researcher on the same activity—the children were divided in two teams; each team sat on the opposite side of the mat. In the first part of the activity the children had to direct the robot to the opposite team by choosing the color card to put the robot on, as the orientation of the robot was defined by the researcher and could not be changed (see Figure 2).

Fig. 2. Three moments of Activity #3. From left to right: child selecting were to place the robot with fixed orientation to reach the opposite site of the mat; child selecting a color card that will be placed on the floor to avoid that the robot escape from the circle formed by the children; child rotating the robot to reach the purple card.

Then we discovered a new card—a purple card that makes the robot turn all the lights purple and spin on the spot. This card was used as a destination card in the second part of the activity. The purple card was placed next to the opposite team and color cards were placed in front of the team that was handling Robotito. The child that was on task had to reach the purple card by rotating the robot and putting it in the correct place on the mat (see Figure 2). Each child did both—chose the color card and rotated the robot.

In the final part of the session we proposed a more open-ended activity in which the children were sitting in a circle and one child was putting color cards in the robot's path to prevent it from leaving the circle (see Figure 2). After the child selected the color of the card and put it in the robot's trajectory, the color cards were passed to the next child.

Activity #4. Total time: 40 minutes. In this activity the children interacted with an Android application that was simulating Robotito, 4 x 4 mat and color cards (see Figure 3). We first explained the app on TV to the whole group and solved together with children some example tasks. The children worked in pairs changing the person that is in charge of programming on the tablet. The programmer had to choose color cards to guide the robot to the purple card. Once reached the purple card, the child drew a smiling face on the A4 paper sheet to mark that the task was fulfilled and passed the tablet to its partner that proceeded with the next task.

Activity #5. Total time: 40 minutes. The class was divided into two groups. The first group worked in pairs on on-paper tasks in which the children had to paint already fixed coding card with the the right colors to make the robot reach the purple card, or define the place and the color of the cards that direct the robot to the purple card and draw them on the paper grid.

The second group prepared a square-shaped path that was used to introduce the new orange card. We imagined what the card would do, and then introduced it to the prepared path and observed how the robot responded to it (see Figure 4). The children were invited to reflect how to activate and deactivate the sound reproduction and to propose routes that integrate an orange card.

Activity #6. Total time: 60 minutes (10 minutes per group). We formed small groups (1 to 3 children) and each group worked with Robotito for about 10 minutes, while the rest of the class performed curricular activities with the teacher. The children in the small group were distributed around the 4 x 4 mat. Each child was invited to code with color cards a L-shaped path from a point next to it to one of the classmates or to the researcher. The initial orientation of the robot,

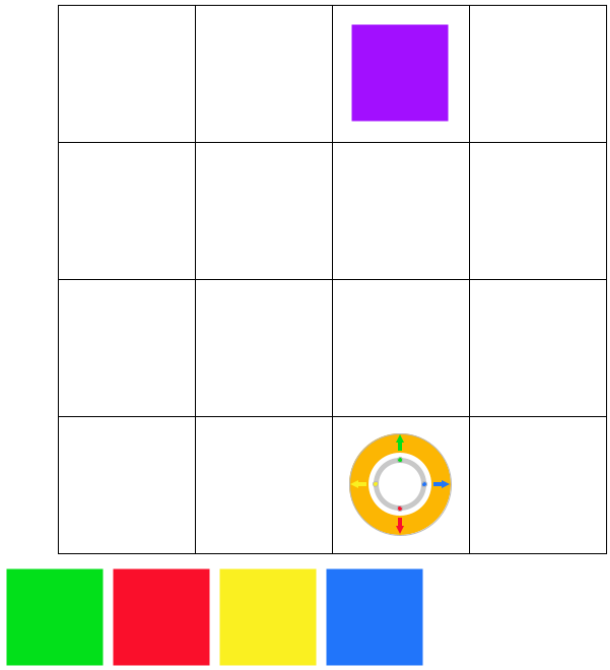


Fig. 3. Screenshot of an Android application simulating programming activity with Robotito.

Fig. 4. Children observing the robot's behavior after passing over the orange card.

the initial position, and the end point were defined by the researcher. In some cases, to make the task more challenging, we used white cards with an X in the middle that indicated that the robot should not pass through that cell. In other cases we asked the child to prepare the path and activate the music before arriving at the end point. All the group members participated in the final task in which they programmed a long path that incorporated music activation and deactivation.

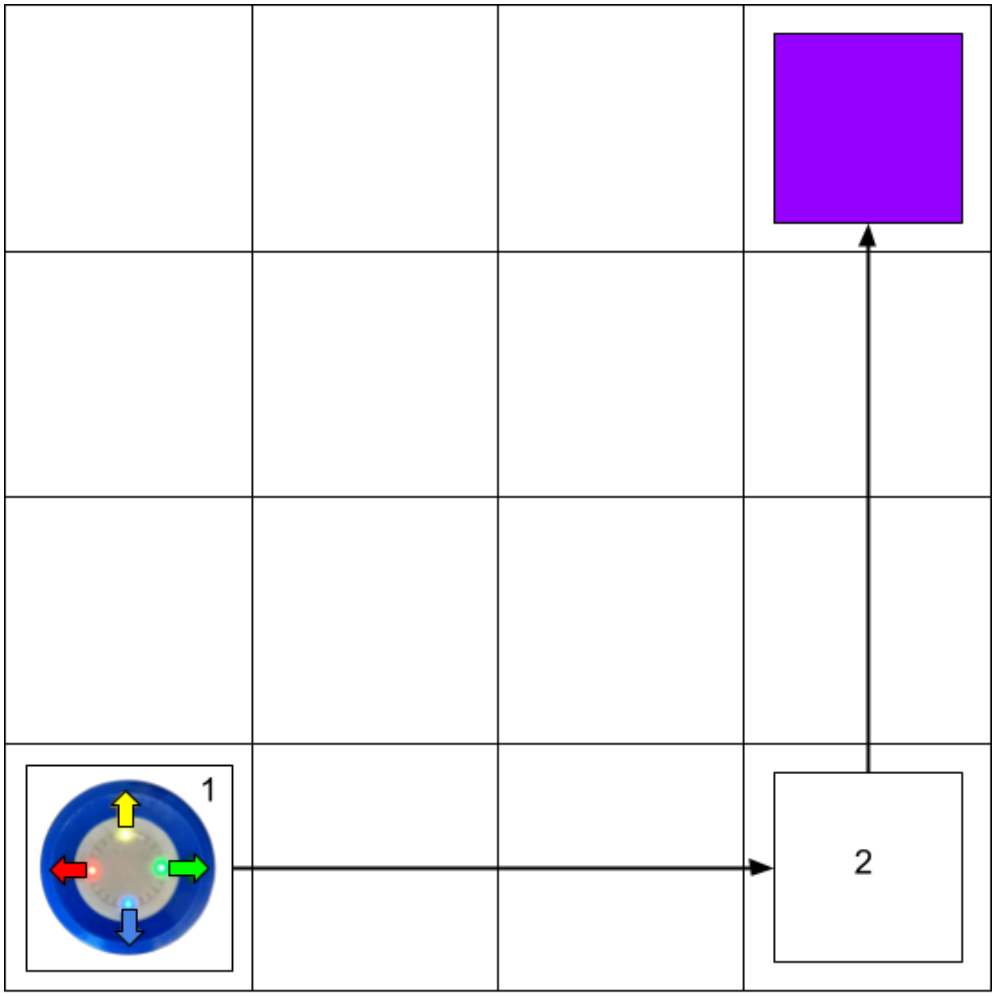
Activity #7. Total time: 30 minutes. The class was divided into two groups and each group worked with one researcher on the same task. First we introduced the pink coding card and thought how Robotito responds to it. After turning on the robot and observing how it acts. The researcher rotated the robot and each child tried to predict in which cell it would stop after sensing the pink card. We ended the session with building paths suggested by the children.

Activity #8. Total time: 75 minutes (10 to 15 per group). We formed small groups (1 to 3 children) and each group worked with Robotito for about 10 to 15 minutes, while the rest of the class performed curricular activities with the teacher. Each child had to solve a task based on combining the pink card (initial point) with other color cards to reach the purple card. In those exercises the rotation of the robot was fixed by the researcher. In the final exercise the children had to predict what happens when we build a diagonal with three pink cards that crosses the mat and end with the purple card.

B ROBOTITO TEST

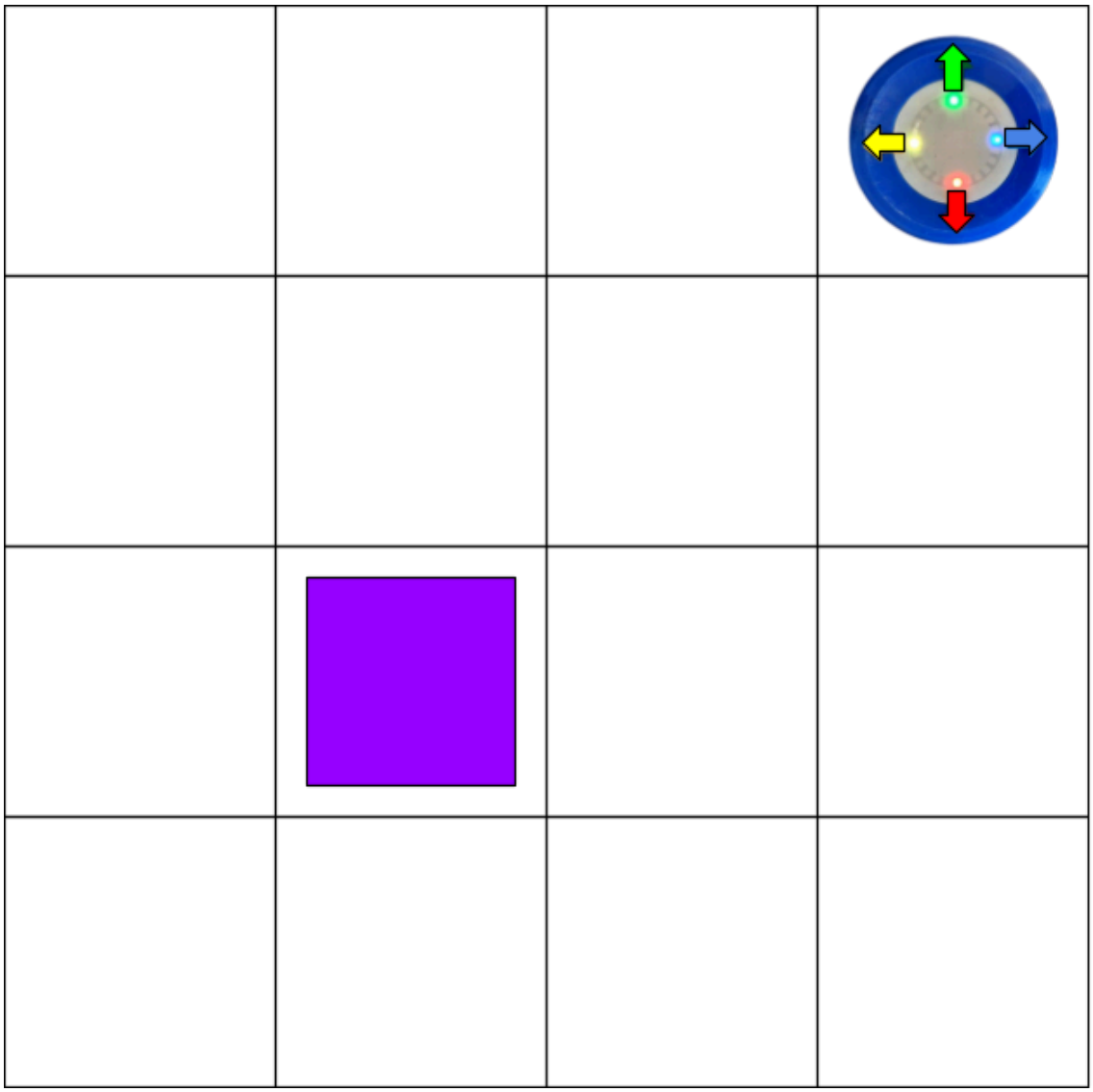
Task 1

What color (yellow, red, green, blue) should cards 1 and 2 be for the Robotito to reach the purple card?



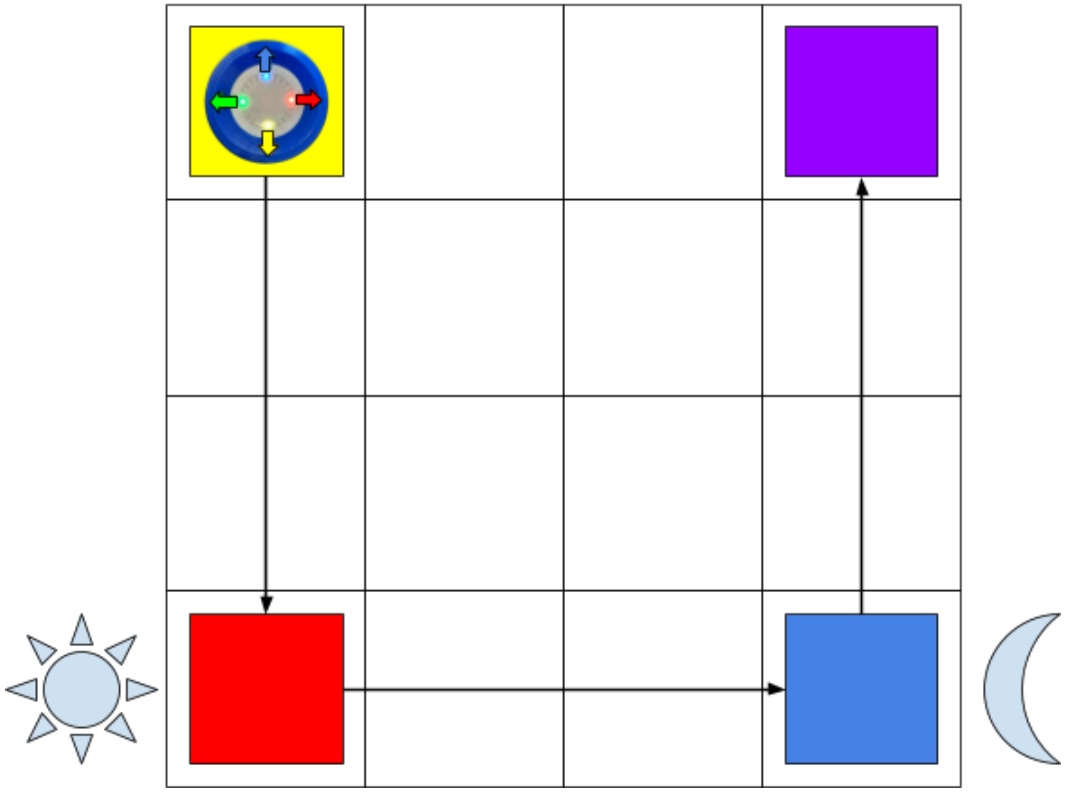
Task 2

Place the cards so that the Robotito reaches the purple card. Select what color they should be and where to place them.



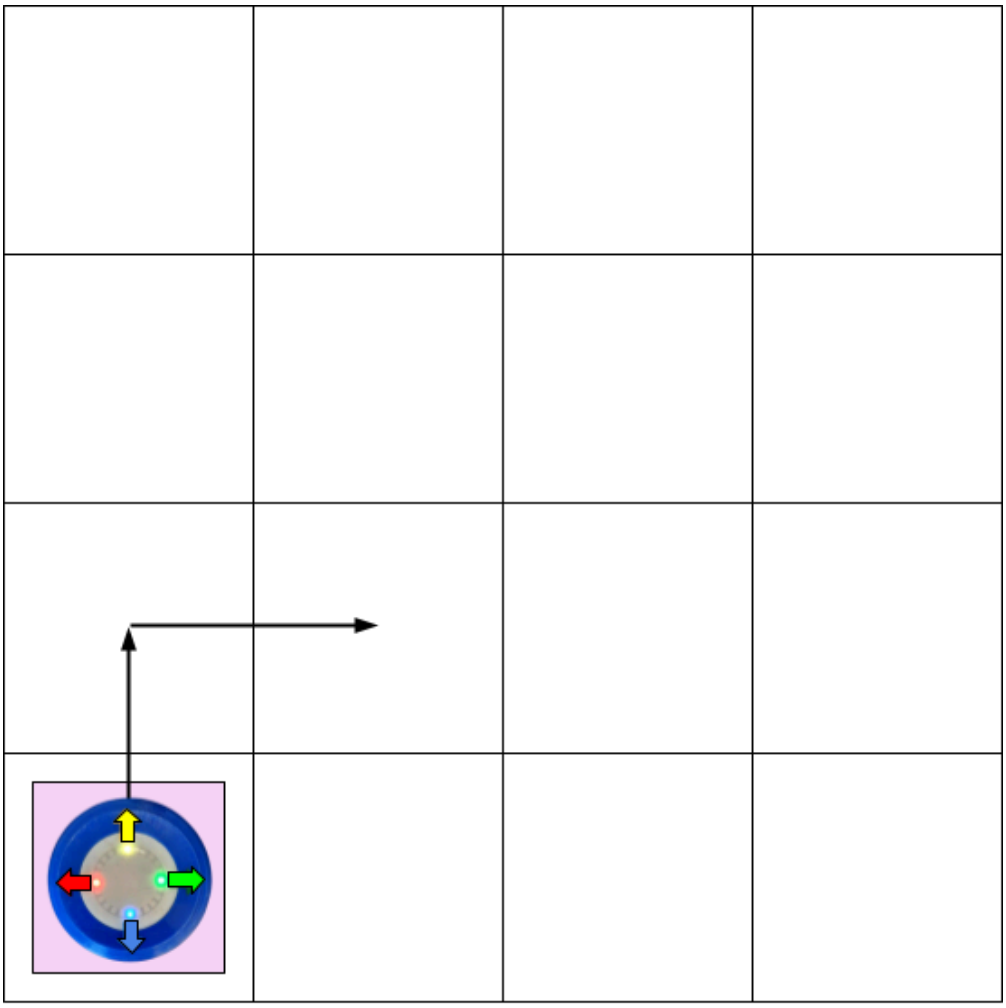
Task 3

The Robotito is going for a walk to reach the purple card. Along the way, it must make a sound near the sun and stay silent near the moon. Where should we place the orange cards so that the Robotito makes sounds near the sun and stays silent near the moon?

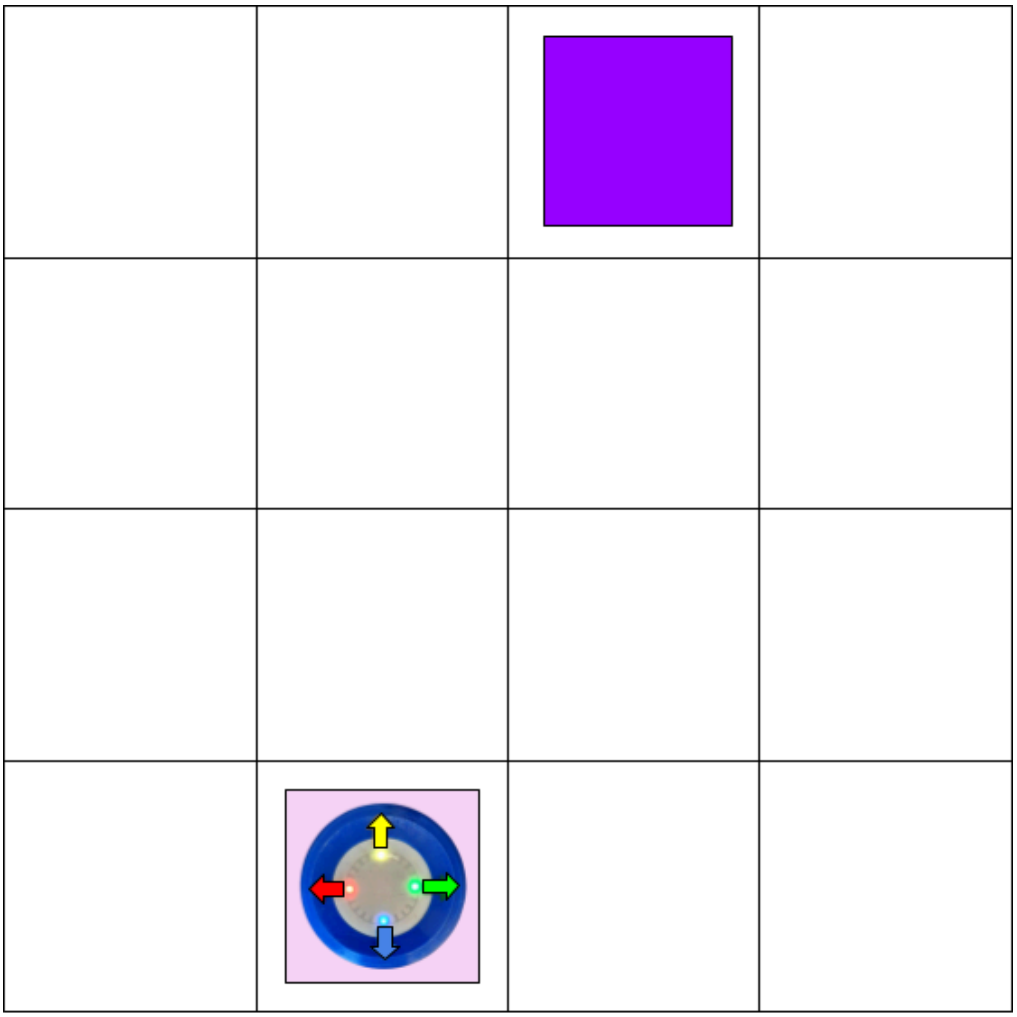


Task 4

The Robotito uses the pink card to go forward and to the right side.



Robotito starts on the pink card, what card should be added and where for it to reach the purple card?



C ROBOTITO TEST RESULTS

ID	GROUP	P1	P2	P3	P4
A2-1	A2	1	1	1	1
A2-2	A2	1	1	0	1
A2-3	A2	1	0	0	1
A2-4	A2	1	1	1	1
A2-5	A2	1	1	0	1
A2-6	A2	1	0	1	1
A2-7	A2	1	1	1	1
A2-8	A2	1	1	0	1
A2-9	A2	1	1	1	0
A2-10	A2	1	1	1	1
A2-11	A2	1	1	1	1
A2-12	A2	1	1	0	0
A2-13	A2	1	1	0	0
A2-14	A2	1	0	0	0
A2-15	A2	1	0	0	0
A2-16	A2	1	1	0	1
A2-17	A2	1	1	1	1
A2-18	A2	1	1	1	1
A2-19	A2	1	1	0	1
A1-1	A1	1	1	0	1
A1-2	A1	1	0	0	0
A1-3	A1	1	1	1	1
A1-4	A1	1	1	1	1
A1-5	A1	1	1	1	1
A1-6	A1	1	1	1	0
A1-7	A1	1	1	1	1
A1-8	A1	1	0	1	0
A1-9	A1	1	1	1	0
A1-10	A1	1	1	0	0
A1-11	A1	1	1	1	1
A1-12	A1	1	1	0	0
A1-13	A1	1	0	0	0
A1-14	A1	1	1	0	1
A1-15	A1	1	1	1	1
A1-16	A1	1	0	1	0
A1-17	A1	1	1	1	0