“It will surely fall”: Exploring Teachers’ Perspectives on Commercial Robots for Preschoolers

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This paper presents a study with kindergarten teachers to assess the advantages, challenges and opportunities of commercial robots to teach computational thinking to young children. Recent studies have highlighted the potential benefits of introducing CT concepts at an early stage. Robots are an engaging and effective educational tool for teaching CT to young children, providing hands-on and interactive learning experiences. Entirely tangible robotic environments have successfully connected the abstract world of CT with the concrete world of preschoolers. Children can program robots by pressing buttons, drawing the path or using code cards. However, there is limited research on the use of commercial robots in preschool classrooms. This research aims to address this gap by investigating preschool teachers’ perspectives on the advantages, challenges, and opportunities associated with using commercial robots in the context of kindergarten classrooms. We contribute with a list of practical, pedagogical and motivational aspects that should be taken into account while evaluating robots and design considerations to build robotic environments for kindergarten classrooms.

CCS Concepts: • **Human-centered computing → Interactive systems and tools**; • **Social and professional topics** → *Children.*

Additional Key Words and Phrases: Educational robotics, Preschoolers, Teachers’ perspective

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1 INTRODUCTION

In today’s rapidly advancing technological landscape, computational thinking (CT) has emerged as a crucial skill for individuals of all ages. Defined as an approach that uses computer science concepts to solve problems [28, 29], CT plays a pivotal role in using computers as a creative tool and supporting problem-solving in the digital age. By integrating CT into school curricula, educators can foster critical cognitive abilities, including abstraction, algorithmic thinking, automation, decomposition, debugging, and generalization [7]. While traditionally perceived as a domain for older students, recent research has highlighted the potential benefits of introducing CT at an early age, particularly during the preschool years [21, 23, 26, 27].

Among the various educational tools available, robots have garnered attention as effective vehicles for teaching CT to young children. They offer a tangible and interactive learning experience that captivates preschoolers’ imagination and engages them in the learning process. The physical presence of robots provides a unique advantage over traditional educational approaches by enabling hands-on exploration and experiential learning.

Tangible user interfaces (TUIs) for programming, in particular, have resulted as an appropriate method for introducing CT concepts to young children. These interfaces utilize physical objects such as tiles, blocks, or cards that children can manipulate and arrange to create simple programs. By associating physical actions with coding concepts, TUIs bridge the gap between the abstract world of CT and the concrete world of preschoolers, making the learning process more accessible and enjoyable. Empirical studies have provided evidence that interventions with robots programmed using TUIs were associated with preschoolers being able to improve skills such as sequencing [1, 6, 10, 11, 16, 17, 22, 25, 26], problem solving [17, 25], debugging [1, 6, 12, 16, 22] and even effectively employing control structures (conditionals and loops) [6, 22] that are essential for the construction of advanced algorithms [15].

Despite the proliferation of commercial robots on the market, most of these devices are designed for individual use, focusing primarily on entertainment. Consequently, there is a lack of research and development surrounding the use of robots in a preschool classroom setting, considering use by groups of children. As we mentioned before, many articles report the use of commercial robots for preschoolers in empirical studies. However, evaluating the robot's appropriateness for classroom activities is almost never the focus of those scientific communications. In a few cases, there are specific comments on child-robot interaction; for example, "authors hypothesized that the use of an external memory system for keeping a visual record of the commands used to program the Bee-Bot would be necessary for effectively scaffolding children's learning" in [1] or "even though we had gone through this set of activities with our K1 students (aged 3 to 4), they did not fully comprehend those vocabularies/instructions (e.g., turn left/right) used in the Bee-Bot activity" in [26]. The studies generally focus on one particular robot and evaluate its effectiveness in CT development. If present, the observations related to the interaction are made by the researchers conducting the activities. In our previous work [3], we evaluated multiple robots in a classroom setting, but the observations were made by the authors and focused on group interaction. To our knowledge, none of the previous studies sought the views of teachers on multiple robots for preschoolers.

Recognizing this gap, we evaluated four commercial robots with two preschool teachers to gather their perspectives on the use of robots in their classrooms and their potential for effectively teaching programming concepts such as sequences and control structures. The following research question guided this work: What are the perceived advantages, challenges, and opportunities of commercial robots to be implemented in a preschool classroom, according to teachers?

2 METHODOLOGY

Between March and May 2023, we conducted five focus groups with two preschool computing teachers from a private educational center in Montevideo. Both teachers have more than ten years of teaching experience in public and private institutions and work at the preschool and primary school level. The study protocol was approved by the Ethics Board of the lead institution and all methods were in accordance with the Declaration of Helsinki [2].

2.1 Robots

We evaluated four tangible off-the-shelf commercial robots: Qobo [24], Ozobot [19], KIBO [13] and Botley [14]. We selected them as they can be programmed using tangible interfaces and offer the possibility to program with control structures.

Qobo is a snail-like robot with two acting modes: game mode and free mode. In the game mode, children connect tangible puzzle-shaped cards to guide the robot from the start position (game mode card) to the destination card (gem card). The robot senses the cards and moves according to the instruction associated with each card. Free mode enables users to scan the cards and execute the stored program without coding cards below the robot. The conditional card (banana left, apple right) allows directing the robot left or right according to the previous input (banana or apple card).

Ozobot follows a black line and responds to color codes composed of three colors [18] with changes in its behavior. The color codes can change the robot's speed, start a special movement (like zig-zag or spin) or define the robot's direction in the next bifurcation (left, straight, or right).

KIBO can be programmed by scanning barcodes printed on wooden blocks used to build the sequence of orders. Depending on the kit, it can include different sensors and actuators. It counts with an if-block that can be combined with "near," "far," "light," and "dark" conditions.

Botley comes with two modes: "line" and "code." In the "line" mode, it follows black lines; in "code" mode, it can be programmed using a remote control. The child can press buttons on the remote control that define the robot's sequence of actions (main program) and send the program to the robot with the green "transmit" button. Conditionals can be implemented by defining actions the robot will execute if an obstacle is detected (conditional program).

2.2 Procedure

We evaluated one robot per session with two teachers (sessions 1-4). Sessions started with a brief introduction of the robot, its functions, and how to program it. Then, teachers explored it independently, prepared simple programs, and commented on their impressions about the robot. To further fuel the discussion, we asked teachers to point out the advantages, challenges, and opportunities each robot has in their opinion and how they envision using them in their kindergarten classrooms.

The sessions were video recorded, and two researchers performed a reflexive thematic analysis [8] of the videos from the focus group with teachers. We followed a mixed coding approach, where we designed the first codebook and inductively extended it with observed codes. We went back to teachers to triangulate our results and enrich our analyses. We presented the analyzed themes to confirm our findings' correctness, to consult items we had doubts about, and to gather new feedback after classroom activities that the teachers implemented with Ozobot, Qobo, and KIBO (session 5). Results from session 5 allowed us to have a more profound understanding of their opinion and identify new relevant aspects that emerged during classroom activities.

3 RESULTS

During the thematic analysis, we identified three relevant themes: practical (e.g., size, battery duration, fragility), pedagogical (e.g., concepts that can be explored, appropriateness of the programming interface), and motivational (e.g., attractive design or children's interests) aspects. We used these themes to classify teachers' comments. Here, we present the results of the evaluation of each robot (see Table 1), a summary of relevant items that can be evaluated in robots in general (see Appendix A), and considerations related to the use of the robots in a classroom context.

3.1 Robots' Evaluation

Each robot was analyzed considering the comments in all five focus groups.

3.1.1 Qobo. Many practical aspects were mentioned as Qobo's strengths. Both teachers, T1 and T2, considered that its size and shape were appropriate for young users because they could lift it with just one hand and grab it easily due

		Strenghts	Weaknesses	Opportunities
Qobo	practical	size	step size	
		form	expensive to fix and mantain	
		battery charging	inexpected bahaviours	
		battery duration		
		movements precision		
	pedagocical	no previous work required	interaction with sensors	mat for loops
		program-robot distance	no loop in play mode	accessibility of coding cards
		errors detection	limited loop in free mode	connection with teaching curriculum
		multimodal output	conditional too rigid	
		guidance during the activity	amount of conditionals	
		interaction with the child	confusing mat	
	motivational	interaction with the child	little innovative	
Ozobot	practical	size	movements precision	simplify color codes drawing
			color codes detection	change color codes to icons
			battery duration	stickers with color codes
			form	
			fragility	
			expensive to fix and mantain	
			color codes drawing	
	pedagocical		color codes complexity	codes with inverse reading
			target age	previous work with color codes
			collaboration	connection with teaching curriculum
	motivational	innovative		
		fun codes		
		design		
KIBO	practical	coding blocks size	size	program uploading
		coding blocks form	fragility	
			color of the light blocks	
			no color relation between blocks and sensors/actuators	
			program uploading	
			program decomposition while uploading	
			amount of programming blocks	
			precision of light/dark concept	
			expensive to fix and mantain	
	pedagocical	advanced programming synatx (begin-end)	program-robot distance	suitable for older children
		interaction with sensors		connection with teaching curriculum
		control over diverse actuators		
		unique evaluation of if-statement		
Botley	practical	size	size	
		roboust	fragility	
		auxilary cards - colors	auxilary cards - time	
		program uploading	auxilary cards - easy to disorder	
		extension of the uploaded program	step size	
			velocity	
			expensive to fix and mantain	
	pedagocical	auxilary cards - visibility of the program	program-robot distance	connection with teaching curriculum
			no program visibility	
			auxiliary cards placement	
			loops - sintaxis	
			conditionals - sintaxis	
			conditionals - prediction of the secuence	
			conditionals - cognitive demand	
			auditive feedback	
	motivational	design		

Table 1. Relevant practical, pedagogical and motivational aspects for each robot.

to its form. Both observed that the robot was very precise in its movements while executing the program. They also considered that charging its battery via microUSB was very practical.

From a pedagogical point of view, T2 was enthusiastic about the vocalization that is used to reinforce the robot's actions (for example, it says "forward!" when it passes over a coding card that makes it move forward) and to guide the programming activity (it provides audio clues indicating where to put the robot and how). She considered it beneficial that "it reinforces the visual output with audio [...] it (the information) enters by two senses" and, by guiding the child, "promotes autonomy". Coding cards in puzzle form were considered a clear and direct programming interface. Both teachers agreed that they helped to visualize the program; T2 mentioned that "the sequence is visually explicit" and that the interface "is super clear when programming an algorithm." Many times during the focus groups, T2 mentioned program-robot distance as an important aspect at the preschool level, in case of Qobo she considered that the distance is very low as the robot moves over the programming cards and the child can easily follow the program execution. She also considered the puzzle shape of the cards helpful while preparing the program. The puzzle form indicates where the following command should be attached, and so prevents programming syntax errors. Cards that require a child's action (jiggles or lifting the robot) were polemic. T1 considered that they "create a motivation," "reinforce what a command is," and "help children to focus on the program execution," as the robot does not execute the following steps if the child does not interact with it. T2 appreciated its motivational aspects but doubted its pedagogical use.

Although the coding puzzle cards were positively evaluated as a programming interface, their size was considered limiting, as they did not allow building long and complex paths with children working at the classroom tables. Also, T2 mentioned that the cards could have tangible clues for children with low vision or blind. The teachers were also not satisfied with the implementation of the loops as the free mode has only a fixed number of repetitions (3 or 6 times), and the game mode did not support loops. T2 proposed a mat with repeated patterns (for example, concatenated L-shaped road units) that could support the teaching of the loop concept. Also, the implementation of conditionals was considered not very challenging and too rigid and the teachers expressed the desire to be able to work with more diverse conditionals.

Although the teachers noticed some unexpected behaviors and considered the robot expensive to fix and maintain (like all robots in Uruguay), they saw many possibilities to connect programming activities with other curricular contents. T1 stated that "it has many possibilities" and "you can integrate it with a lot of things" and named mathematics (counting, sequencing, geometry, probability, magnitudes, sets), spatial positioning, and social bonding.

Qobo was the first robot discussed in a focus group; T2 used it in informatics classes with children of level 4 (3 to 4 years old) after the focus group. T1 also assisted in some of those instances, and both shared their observations in the final focus group. They agreed that Qobo does not require preliminary work with children, contrary to other robots analyzed in the focus groups. They were surprised by the battery duration ("I never charged it!" stated T2) but disappointed with the card materials as some card tips began to peel off. They complained about the mat because the children were too influenced by its design (they tried to follow the painted roads with the path they were building and avoided places where water was drawn, see [24] to consult the mat design). T1 preferred a clean white mat with a grid, "I do not like anything that structures it so much," she said and claimed that too much structure limits the activities and makes it difficult to work with the robot over a sustained period of time.

T1 observed that although the puzzle-shaped form had the potential to prevent errors, some children ignored that the cards should be connected to each other and committed programming errors anyway. They thought it could be beneficial to have both puzzles that define the place to concatenate the following command (current version) and cards with no obvious place to continue the program. They proposed square-shaped cards with no inserts or cards with multiple inserts that allow concatenating commands in incorrect positions. They considered that they could be more challenging for older children and allow them to learn from errors.

The opportunity to see other robots (specially KIBO) made them notice that Qobo's interaction with the environment using sensors is limited and could be extended.

In general, they found Qobo very appropriate for the preschool level. However, they admitted that it is not innovative and has a "low ceiling" and that it would be difficult to use it over a sustained period of time.

3.1.2 Ozobot. Its small size and transparent body which allow children to observe its circuits inside were mentioned as aspects that makes it curious and attractive. Before using Ozobot with children, teachers mentioned that the size could be a practical weakness as it seems too small and fragile "I do not see it as robust, I am afraid that it could fall down and 'puff' [does not work anymore]" - T2. However, after using it, they mentioned that the weakness was not the size but its shape. They suggested that a more secure casing or shape could prevent the robot from falling.

A motivational aspect, much appreciated by the teachers, was the possibility to draw its path: "Hand tracing has a relationship with art that I like! It's free, it's innovative and creative, and it connects with other things about the child, previous experiences, and that makes them more enthusiastic [...] I like it with markers instead of cards. I think this can be more open, and children may be more involved in the design" - T2. Also, some features and codes such as "tornado" (the robot spins) and "turbo" (the robot changes its speed to go super fast) were considered motivational factors that could engage and motivate children to play with the Ozobot. The teachers identified several opportunities for using it in the classroom. The use of codes and observing Ozobot's behavior was seen as a way to develop logical reasoning and work on various skills such as path recognition, serialization, directionality, and mathematical concepts like sequences, perimeter, and amplitude. The teachers believed that Ozobot had the potential to remain relevant and not become deprecated in terms of its didactic aspects.

The teachers evaluated Ozobot's weaknesses and commented on practical and didactic aspects. Regarding the didactic aspects, T2 questioned us about the complexity of the options to program the robot: "Why did they [the developers] choose color codes instead of using icons?" She was negatively surprised about this limitation. She also mentioned that so many color codes would be confusing for children and that limiting the number of color codes to three would be better. Also, T2 expressed concern about the difficulty children might face in accurately painting the color code in the black line that Ozobot follows. To address concerns about using color codes with young children, the teachers made several suggestions, such as using small squares or stencils for children to paint inside, making the process more manageable, stickers with codes or paths, including curves and straight lines, etc. T2 proposed making the colors more similar to icons to help children focus on the symbol's meaning rather than memorizing abstract color associations.

T2 also mentioned the challenge of precise line drawing for the robot "is very difficult for children. It is not the instruction per se but the instruction format.[...] it is about how children draw and the possible challenges for the robot as their lines and drawings are imprecise." In terms of practical aspects, the teachers mentioned issues with the reading sensor and battery autonomy. After using it with children, the teachers observed that it struggled to distinguish between black and blue lines under certain lighting conditions or when the robot had a low battery. This practical weakness was further exemplified when the Ozobot, after performing several spins during the "tornado" function, often ended up off the line and could not continue its intended path. T1 commented: "It was very difficult to draw the circuits - you have to explain a lot of things - the lines could not be wide or thin, the color intensity, when the battery is running out it makes mistakes. [But because of that] we started to talk a lot about the mistakes. They [the children] started to realize it, that the color sensor was failing." Despite these practical challenges, the teachers appreciated how these issues prompted discussions about the robot's limitations and encouraged students to recognize them.

The teachers also stressed the importance of providing prior training to children to understand robot's responses to the codes and the idea of color patterns that codify actions. They suggested creating a path on the floor and make children follow the path and simulate robot's responses and a pattern recognition activities in which one child uses a secret code to send a message that the other child should try to discover. To encourage collaboration, the teachers suggested that drawing activities could provide children more opportunities to work together than using separate pieces, as seen with Qobo. They recommended using larger sheets to accommodate the robot's trajectory to allow for collaborative work: "the collaboration comes from making the drawings. It could be more collaboration than using pieces, as with the Qobo. Because the robot is so small, its trajectory could be big. We could use a big sheet so they could collaborate."- T2. Overall, the teachers recognized the strengths of Ozobot, such as its ability to motivate and engage children, the opportunity to draw paths, and the potential for various learning activities. They also identified areas for improvement, particularly in simplifying the color codes and addressing practical issues with sensor reading, battery autonomy, and fragility. The teachers envisioned strategies for collaboration and provided suggestions for using Ozobot effectively with young children, including prior training and incorporating more accessible elements like icons or stickers.

3.1.3 KIBO. T2 appreciated KIBO's design, mentioning that it aligned well with Waldorf's pedagogy [5]. In terms of practical aspects, they mentioned the blocks' size, the "begin" and "end" commands, and how they fit together. They liked how the blocks fit together easily, making them suitable for young children. T2 said, "I like how they fit together, their size... Even kids three years olds can do it." She also mentioned that the "begin" and "end" blocks allow children to easily understand where the sequence starts and ends and also help children to get familiarized with advanced programming syntax, similar to actual coding.

In terms of didactic aspects, T1 praised KIBO's sensors and actuators, considering them comprehensive and exciting: "I am excited; this is so complete. And it has several actuators." Teachers preferred KIBO's if-statement evaluation, which occurs only once, compared to Botley's continuous evaluation, which makes the robot's behavior difficult to predict.

The greatest KIBO weaknesses and threats detected were related to practical aspects. The most mentioned negative practical aspect was related to uploading the created programs, which was deemed difficult and not child-friendly: "I do not like this part, it is not for children, will not be easy for children"- T2 and T1 added: "to upload the program we should upload the blocks one by one, which is difficult with children [...] otherwise children would upload the nearest blocks, and it would be very confusing.[...] I really like KIBO, but if we cannot upload the program, I cannot use it either!"- T2. When the teachers interacted with KIBO, they struggled to upload the program. They even made an analogy with self-checkout kiosks at supermarkets, which are also difficult sometimes. T2 mentioned, "I wouldn't mind if the child did the sequence and I loaded the sequence... But if I can't do it either… I would not use this for preschoolers because the reading instructions would generate a lot of frustration and little self-regulation." And T1 said: "I also got frustrated [not only the kids]." Another negative aspect not appreciated by the teachers was the design of KIBO. It was considered too big and fragile.

After using it with children, the teacher reinforced some of their previous expectations with KIBO. The teachers did not like KIBO's design inconsistencies, such as no color match between the coding blocks and sensors and actuators. Also, the blocks related to light control were confusing as the background color has more presence than the color of the icon, which indicates what color the light will be. Also, the light icon was confusing (e.g.: "the light seems like a spider without two legs"- T1).

A negative didactic aspect was related to the program's location outside the robot and the need to decompose it hindered understanding and execution. Also, there was the need to decompose the program (blocks fitted together) to scan one by one. So, when grabbing each block to put on the front of the scanner, they did not fit it again when returning the block to the table, making it hard to understand the program and the robot's execution.

The "if" statement was initially thought to be challenging for children but was found to be understandable after using KIBO. However, other negative issues emerged after using it with children, such as the limited quantity of directional blocks. The "if dark" statement was unclear in its operation.

The teachers detected opportunities connected to the curriculum. Some motivational aspects were mentioned, such as that KIBO could be integrated into the curriculum, connecting with information technology concepts and storytelling (a motivational aspect). For instance, if it is dark, the robot could turn the light on (use a light sensor). Suggestions were made for additional features, such as incorporating a pencil: T2 asked, "could we add a pencil? [after KIBO made a path in the form of a square] and the square is visually captured." When we presented a little sign that can be used at the top of KIBO, T2 said: "it would be great if it could take a message to another child at another table," enabling message delivery between tables. Finally, teachers considered KIBO suitable for older children, even in third and fourth grade.

3.1.4 Botley. The most discussed aspects of Botley were the auxiliary cards and the implementation of control structures. Auxiliary cards are paper cards with color arrows that indicate Botley's four movement directions and are used to visualize the program before uploading it to the robot using the remote control. T1 liked the idea of first thinking and preparing the sequence and then uploading the program. She also appreciated that the colors of the arrows on the cards match the colors of the remote control buttons, making the program upload very easy: "I really like the card with the color because it does not give me much chance to commit errors." Remote control as a programming interface was considered simple and fast, but the teachers admitted that, if using only remote control without auxiliary cards, it was difficult to visualize the program. T2 previously worked with Botley and was not so enthusiastic about the auxiliary card: "In the end, I do not use them because it takes too much time" and that "they are not for classroom use" as it is easy to mess them up accidentally. She also did not like that they increase the distance between the program and the robot - the child has to first prepare the cards, then use the remote control to upload the program, and then the robot executes the corresponding actions: "There are three steps; the child got lost [...] it has to be more instantaneous."

How to order the auxiliary cards on the table while preparing the program was also an issue that underwent heavy discussion and none of the options seemed to satisfy both teachers. For T2 putting one next to the other, from left to right, was a convincing option. "For me, the best thing is to put it like this, as you read a story, a word," but T1 was more keen to put the following arrow command at the end of the current, simulating the robot's movement in space. This spatial placement did not fully represent the corresponding robot movements as the robot rotates in place, and the arrow on the turning card gives the impression that the robot will move to the side.

Also, the cards' order to represent loops was not convincing. As the loop button is used to start the loop and repeat it (there is no numerical parameter to indicate the number of repetitions) and there is no end-loop command, the teachers found it difficult to visually order the cards and explain how the commands will be executed. T2 found that "The way in which it should be entered is not the way in which the child can reason about it and be clear as to what will happen" and was doubting whether it was appropriate for kindergarten "It says it is for children aged 5; I do not think that a 5-year-old child can do it". T1 also noticed that due to the syntax, it is impossible to execute one loop and immediately the second one as Botley interprets it as loop - commands - start loop, instead of loop - loop.

The same problem with the visual representation of the program was present while working with conditionals. The conditionals are associated with object detection, and the commands associated with it can be executed at any moment of the main program and more than once. The robot is constantly sensing the environment, and the conditional commands can be executed at the beginning of the programming step, in the middle, and even after the whole program is executed. The impossibility of predicting when the object will be detected made it difficult to visually represent the sequence of actions the robot will take. T1 considered the program's syntax confusing as it did not reflect the sequence of the robot's actions.

Both teachers complained that they can not prepare a program if they do not know when the obstacle will be detected. T1 said, "Yes, it is difficult to have a conditional and not know what obstacles it detects and when; it is also difficult to see if you have executed the entire program". T2 tried to think of an exercise in which the robot goes from A to B in the grid using conditionals but was not able to combine the main program (moving forward) with object detection as she was not sure if the obstacle in front of the robot will be detected during the first forward step or at the beginning of the second one: "What happens here is that it is not just 'always forward,' you have to put how many times." They were complaining that the robot "does not do the same thing twice" (T1) and "it prevents me from reaching my goal" (T2). T1 commented, "The problem with this is that with all the kids working around it, all the time, it's going to be detecting things in front." Both were not able to come up with a reasonable example of a problem that could be resolved using conditionals. T2 stated, "I do not know how to use it with conditionals." She also considered that it is complex and too demanding for preschoolers to prepare and follow two parallel programs (main and conditional program).

Botley stores the last uploaded program, and pressing directional buttons after uploading adds new commands to the current program. The teachers liked this possibility, although T2 said that when working with preschoolers, she always asks them to start the program with the trash button that removes the previously uploaded program and then upload the program from the beginning.

With respect to its size and fragility, the teachers considered it the correct size but did not like that children need to use two hands to lift it. T1 considered that it "seems quite robust," but T2 saw it as fragile, as she had already discussed a classroom accident in which the robot fell down and its wheel stopped working.

Both agreed that the robot moves too fast, making it difficult for children to follow the uploaded program. They missed audio feedback reinforcing the robot's actions, and its steps were considered too big. T2 complained that if you want to count up to 10 (10 movements in a straight line), it will take too much space.

Like all previously evaluated robots, they considered it expensive to fix and maintain and saw multiple opportunities to connect programming activities with other curricular contents.

3.2 Relevant Aspects

We identified diverse practical, pedagogical, and motivational aspects related to the robots' classroom use (see Table 1). We summarized them to provide future research with a list of items relevant for teachers in the classroom context. We adapted robot-specific items (for example, "number of coding blocks" in the case of KIBO) to more general aspects that can be evaluated in robots in general ("number of coding elements"). Some items (for example, auxiliary cards for Botley) were so robot-specific that they could not be generalized and were left apart. In the Appendix A, we present the items grouped by category and a scale to evaluate them using, for example, questionnaires.

3.2.1 General considerations. Many general aspects mentioned by the teachers are relevant when working with robots and children. Available time was a crucial variable to plan activities and define the size of the group. Both teachers stated that working in very small groups (2 to 3 children) or individually is always better. T2 stated, "With the youngest, the fewer, the better" - T2. But both admitted that they usually work with bigger groups due to time constraints. They considered that having more robots would not help provide a better educational experience as the activities with robots require constant supervision and mentioned the "rotative tables" as a strategy they apply to work with smaller groups with constant supervision. They separate children into groups, and each group works at a different table. Some tables do familiar activities that the children can do independently (draw, play with blocks, or on tablets), and one table works with robots under the teacher's supervision. The children rotate so that all of them pass through all tables. T1 mentioned that sometimes not all the children are able to participate in activities with robots, and some groups work with them in one session and others in the following one, and the children are flexible and have no problems accepting the situation. Regarding the area to work with robots, T2 highlighted that she prefers to work on the floor, while T1 preferred to work at the tables: "It does not work for me on the floor; they go all over the place".

Their general comments on the robots' design indicated that they are not designed for group work: "What fails is that it seems to me. . . that in reality they are not meant to be used by more than a few children" - T1. They also admitted that working with robots is always associated with the robots falling from tables, "It will surely fall," stated T1 and T2 confirmed. They positively evaluated robots that can be easily lifted with one hand due to their size and form and imagined protecting materials that could be attached to the robot to absorb the impact.

A common consideration was the preliminary work with children that the robot requires. T1 mentioned that she always first explains what the children will face and what considerations they should have when manipulating the robot. Both agreed that it is essential to first go through embodied experiences related to spatial orientation, sequencing, and directionality. They also mentioned that more complex programming interfaces would benefit from unplugged activities related to challenging concepts, such as working on pattern recognition before using Ozobot's color codes.

We grouped general considerations and relevant aspects by the activity level and presented them in Figure 1.

4 DISCUSSION AND CONCLUSION

This paper addresses teachers' perspectives on commercial robots for preschoolers. By leading focus groups and lending the commercial robots to teachers to use with their pupils, we sought to understand the features the robots should have and other considerations related to classroom use with young children. As teachers play a crucial role in the successful implementation of educational tools, assessing their perspectives and experiences can shed light on the feasibility, usability, and pedagogical value of robots in the preschool classroom. By considering teachers' feedback, this study aims to inform future research and development efforts in designing robots better suited for educational settings. We aimed to contribute to understanding the advantages, challenges, and opportunities associated with using robots as educational tools in the preschool context. Earlier research has indicated that educators exhibit enthusiasm for educational robotics [20] and acknowledge its potential benefits. In our study, teachers were eager to try out some commercial robots they could use in their classrooms. They found that all the robots had the potential to be combined with preschool curricular content, and as vehicles to work on mathematics, spatial abilities, storytelling, and fun activities, such as robot races or making the robot carry messages between groups. However, previous research found that teachers generally hold unfavorable views regarding using robots within educational institutions which has been associated with the technical skills teachers should have to implement robotics curricula [20]. We believe that well-designed robotic kits should not require previous technical knowledge and be accessible to children and teachers, specifically in the context of kindergarten where CT could be taught in a simplistic and intuitive way. We consider that robots could be designed to support teachers instead of burdening them with the responsibility of learning how to use them, and we, as researchers, designers, and developers, should invest our efforts in creating user-friendly robots to be used in real-world contexts, such as educational settings. By doing so, we can alleviate the additional pressure placed on teachers, who already face the demands of an educational curriculum and extensive teaching responsibilities. Our study contributes to understanding how robots could seamlessly be integrated into kindergarten classrooms by contributing a set of design considerations to develop robots for this specific educational environment.

4.1 General Considerations for Developing Robots for Kindergarten

From our findings, we derived general considerations for developing robots to be used in kindergarten, useful for researchers, designers, and developers.

Design considerations for the development and design of a robotic kit (both robot and programming interface):

- ATTRACTIVE DESIGN AND INNOVATIVE INTERACTION. Robotic kits should be attractive and propose new modalities of child-robot interaction that stimulate children's participation and creativity.
- COLOR CONSISTENCY BETWEEN INSTRUCTIONS AND ROBOT. It is important to maintain the same associations of colors throughout the activity.
- NEAREST INSTRUCTIONS AND ROBOT. The children could "get lost" if there are too many steps between the program and the robot's action. To easily follow program execution and support debugging, the program should be close to the robot.
- DIVERSITY OF INSTRUCTIONS. The robotic kit should allow the robot to interact with the user and environment in a variety of ways. It should support loops and conditionals. The instructions should be fun and interesting but also familiarize children with advanced programming syntax ("real coding").
- UPLOADING PROGRAMS SHOULD BE EASY AND INTUITIVE. Programming the robot should not require many steps and the programs should be easy to debug, upload and extend.

Design Considerations for the development and design of features specifically related to the robot:

- MULTIMODAL FEEDBACK. This feature would help reinforce the robot's actions and guide children in the activity. Teachers mentioned that multisensorial cues help to better understand the robot's actions. They also proposed that the robot could guide the activities by, for example, saying where the child has to start the activity and indicating errors and successes.
- ROBUST AND EASILY GRASPABLE WITH ONE HAND. Young children have little hands and are more prone to drop objects from their hands. A robot should be robust [9] because it may fall at some point in the activity. Being easy to grab with one hand could help prevent falls and ensure its durability. At this point, not only does the size matter, but the robot needs to have some affordance to grab it easily without slipping out. As the falling seems inevitable, it could have attached materials to absorb the impact.
- EASY BATTERY CHARGING, EXCHANGE, AND EXTENDED BATTERY DURATION. The battery should have a duration of 30-60 minutes to enable the robot's use in classes. Charging and exchanging batteries should be easy.
- PREDICTABLE AND PRECISE MOVEMENTS AND SHORT STEPS. The robot should not present unexpected behaviors, and its movements should be precise. Long steps and fast movements are potential limitations.
- LOW-COST FIXING AND MAINTENANCE. The robots should be easy to fix and the price of the components should be low.

Programming interface considerations are:

- ADEQUATE MATERIALITY, ACCESSIBILITY, AND AMOUNT OF ELEMENTS: Materials should have an adequate size and form, be made of durable materials, and be accessible for low vision and blind children. The quantity of coding elements should not restrict the programming of long paths.Also, materials should be easy to build and to be replaced.
- INTUITIVE INSTRUCTIONS. The teachers expect clear programming concepts represented in an intuitive way that does not require memorizing the instructions.
- VISIBILITY OF CODE. The instructions should enable users to visualize the program.
- PREVENTING SYNTAX ERRORS. The affordances of the coding elements should prevent syntax errors.

In the future, it would be crucial to incorporate some of the design considerations identified in our study and test them in real-world educational settings to support teachers and engage children in learning CT and bridge the gap between theoretical research and practical implementation. This would also be an opportunity to incorporate children's feedback, which is also crucial for the success of the activities.

5 LIMITATIONS

Access to the robots was a limiting factor of this study, as there are more robots with a tangible programming interface in the market that allow work with control structures. In our previous study, we identified 11 robots (see Table 3 [4]) with tangible user interfaces that allow working with control structures. Although we only worked with four robots, they represent all different types of conditionals and different manners of integration of conditionals with the main program identified in [4].

Another limitation was the size of our focus group. Working with only two teachers allowed us to maintain the same working group over an extended period of time and enrich the evaluations with insights about already evaluated robots that appeared in the following sessions. The teachers that we invited work with preschoolers and have broad experience in teaching computing, which allowed them to better visualize the possible implementation of the robots in classrooms and test them with children.

Another item to remark is that, as we conducted a focus group, not all aspects were discussed for all robots. For example, there were comments on the step size of Qobo and Botley but not on KIBO. With the relevant aspects identified in this work, we plan to conduct a comparative analysis of the four robots to provide a more in-depth evaluation of each robot.

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A RELEVANT ITEMS THAT CAN BE EVALUATED IN ROBOTS

Practical aspects identified:

- General aspects
  - Size (adequate size - too big/small)
  - Form (easy to lift with one hand - difficult to lift with one hand)
  - Fragility (robust - fragile)
  - Cost of fixing and maintaining (cheap to fix and maintain - expensive to fix and maintain)
- Battery

  - Battery charging (battery easy to charge - difficult to charge)
  - Battery duration (lasting long battery - battery goes empty fast)
- Movements
  - Step size (adequate step size - step too big/small)
  - Velocity of movements (moves with correct speed - too slow/fast)
  - Movements precision (precise - imprecise)
  - Unexpected behaviors (presents unexpected behaviors - do not resent unexpected behaviors)
- Coding elements
  - Coding elements size (adequate size of coding elements - coding elements too big/small)
  - Coding elements form (adequate form of coding elements - coding elements difficult to manipulate)
  - Amount of coding elements (sufficient amount of coding elements (blocks, cards) - limited amount of coding elements)
  - Precision of programming concepts (easy to understand commands - too abstract commands)
  - Color coherence between robot and code (colors are used to connect coding elements with the robot - there is no color relation between coding elements and the robot)
- Program uploading
  - Program uploading complexity (easy to upload the program - difficult to upload the program)
  - Uploaded program extension (easy to extend uploaded program - difficult/impossible to extended uploaded program)

Pedagogical aspects were:

- Available commands
  - Interaction with the user (it is possible to incorporate interaction with the users - no interaction with users supported)
  - Interaction with diverse sensors (offers possibility to work with diverse sensors - does not allowed to work with sensors)
  - Control over diverse actuators (allows to control diverse actuators - does not allowed to control actuators)
  - Loops support (allows to incorporate loops easily - does not support loops)
  - Conditionals support
    * Rigidity (flexibility in conditional statement building - conditionals are rigid)
    * Syntax (conditionals syntax easy to understand - complex syntax of conditionals)
    * Cognitive demand (conditional statement is evaluated one time - conditional statement is constantly evaluated)
  - Advanced programming (incorporates advanced programming syntax - does not incorporate advanced programming syntax)
- Coding elements
  - Commands complexity (coding elements are easy to understand - coding elements are abstract and must be learned)
  - Accessibility of coding elements (coding elements are accessible for users with low vision and blind - coding elements are not accessible)

  - Visibility of the program (programming interface makes the program visible - programming interface offers no visual support for the program)
  - Errors detection (coding elements help to detect programming errors - errors are first visible when the robot executes the program)
- Scaffolding
  - Previous work (does not require previous work - requires previous work)
  - Multimodal output (uses multimodal output (movements, lights, sounds) to communicate its actions - does not use multimodal output to communicate its actions)
  - Guidance during activity (guides the activity - does not guide the activity)
- General considerations
  - Connection with teaching curriculum (easy to connect with teaching curriculum - difficult to integrate with classroom activities)
  - Target age (adequate for preschoolers - targets older children)
  - Collaboration (prompts collaboration - designed for the individual use)
  - Program-robot distance (you can program the robot (almost) directly - programming the robot requires too many steps)

Motivational aspects identified were:

- Interaction with the child (can interact with the child - there is no child-robot interaction)
- Attractive design (has attractive design - is not attractive)
- Interesting commands (has fun and engaging commands - the commands are not very engaging)
- Innovation (allows to work in a way that is not possible with other robots - is similar to other robots)

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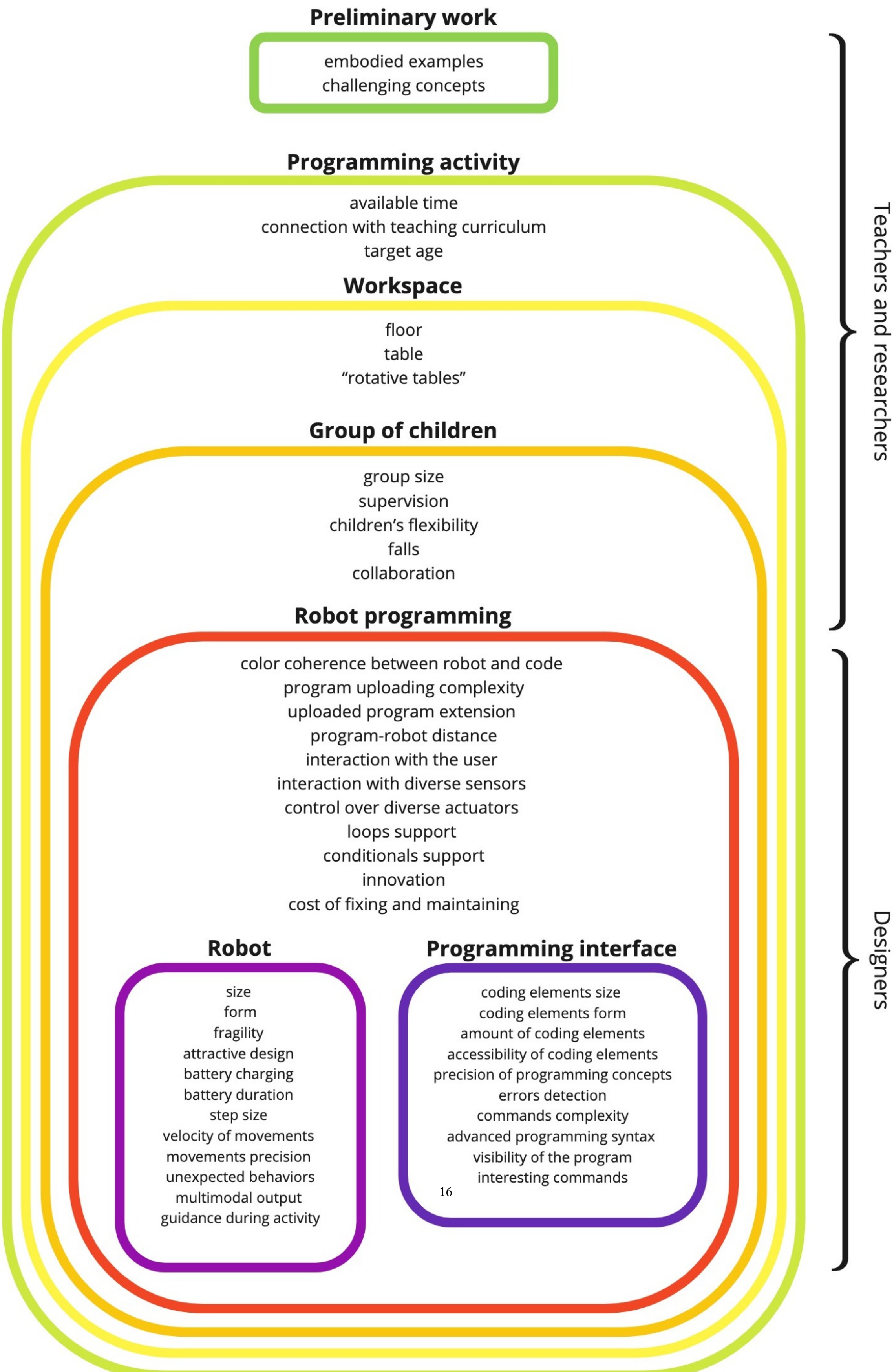

Fig. 1. General considerations and relevant aspects grouped by activity level. We divided the identified items into those more relevant for teachers and researchers and those more specific for robot designers.