Moving Beyond Stereotypes: How Kindergarten Robotics Activities Shape Children's Imaginaries About Robots

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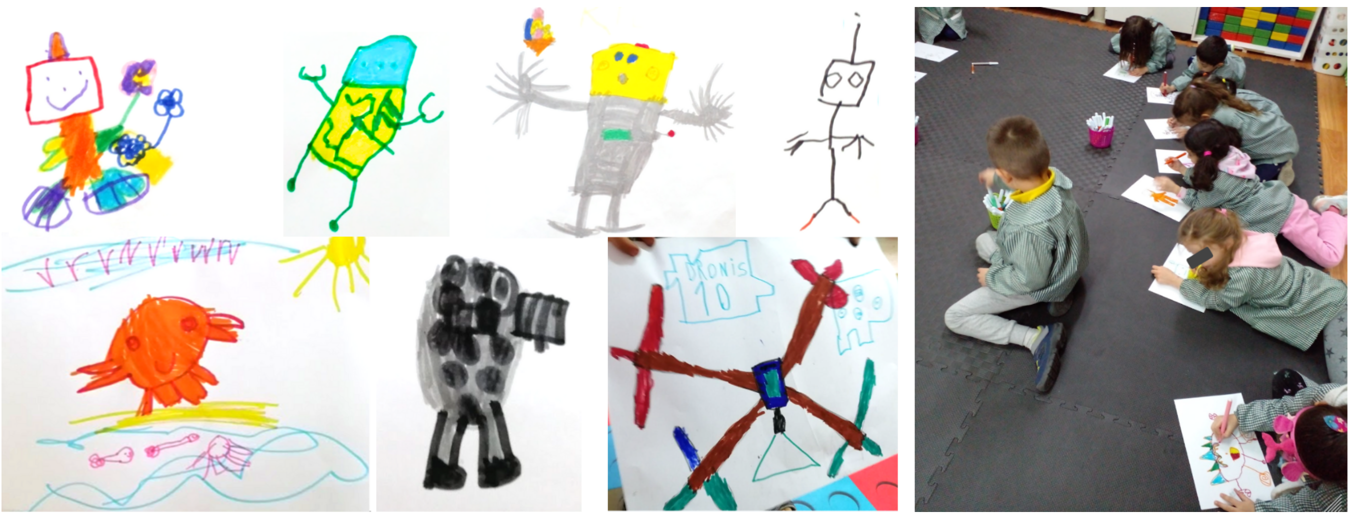

Figure 1: Examples of children's drawings and drawing activity setting.

ABSTRACT

As computing education for children continues to grow, there are increasing calls to go beyond teaching computational thinking to empower children to engage with technology in creative and critical ways. Having an honest and accurate understanding of the nature of computing devices, including those portrayed as smart, could help children with this empowerment goal. Prior research on children's imaginaries and perceptions of robots has had consistent findings across multiple decades, age groups, and geographies, that center around assigning robots human-like characteristics, including problematic ones, such as gender stereotypes, violence, and lack of human control. In this work, we explore the impact of 15 educational robotics (ER) sessions on 30 kindergarten children's imaginaries about robots. Prior to ER activities, children's imaginaries aligned with previous findings, but after the sessions, children were less likely to anthropomorphize robots or assign them gender, and a majority of children envisioned robots under their control.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; • **Social and professional topics** → *K-12 education.*

KEYWORDS

Educational robotics, kindergarten children, imaginaries, ethics, drawings

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1 INTRODUCTION

There has been a sustained resurgence in computing education for elementary and even preschool children during the past 15 years. Wing's call for computational thinking education [56] combined with the availability of child-friendly programming environments (e.g., [4, 35]) and government initiatives (e.g., [11, 49]) are among the factors providing a foundation for this revitalization in computing education for children. This growth in computing education for children has occurred at the same time as computing devices have become more ubiquitous in society and children's lives [22]. Not surprisingly, the importance of computing in today's society has prompted scholars to discuss goals for computing education that go beyond computational thinking and take a broader perspective, including aspects of equity, social justice, and inclusion [42, 54], citizenship and civic life [54], and societal impacts [26, 53]. For example, researchers at Aarhus University have argued going beyond computational thinking to computational empowerment that enables children's creative and critical engagement with technology [15, 24], leading to the development of specific approaches for use in Danish secondary schools [50].

We are also engaged in efforts to expand opportunities for children's computing education, in our case, with a focus on kindergarten children, and in a different region of the world: South America. In this paper, we present the results of a research opportunity that enabled us to learn about kindergarten children's perception of robots before and after a set of educational robotics (ER) activities.

Prior research on children's imaginaries (i.e., how children imagine something could be) about robots typically involves asking children to imagine robots, draw them, and describe them [9, 32–34, 46]. The remarkable aspect of these prior experiences across more than 20 years, different age groups, and multiple countries is that they resulted in very similar children's imaginaries. These involved assigning robots human-like attributes in terms of appearance, behavior, and cognitive abilities (e.g., [19]). These views appear to arise primarily from children's exposure to robots in media and have sometimes carried with them aspects that have concerned researchers, such as those related to gender stereotypes (e.g., male robots fighting) [34], violence (e.g., incorporating lethal weapons) [34], and lack of human control (i.e., robots being fully autonomous) [19, 51].

We identified a research opportunity in that none of these prior research efforts have included exposing children to ER activities for an extended amount of time, which could resemble future ER activities in classrooms. This research opportunity could help us understand the potential impact of classroom-based ER activities on children's perception of robots, which could, in turn, affect their ability to have a critical and creative engagement with them [15, 24]. We, therefore, decided to assess children's imaginaries by asking them to draw and describe imagined robots at the beginning and end of the 15 ER sessions, which took place over 5 months. The context for the research was the need to assess the trade-offs of a set of robots being considered for use in computational thinking activities in public school kindergartens. Our plan was to conduct ER activities with each of the robots in a public school in order to explore their strengths and weaknesses and better understand their desirable characteristics.

We found that the imaginaries before the activities were consistent with prior research, while those after the activities were different, with children less likely to use anthropomorphic representations and gender, with some promising directions in terms of explicitly including forms of human control. In addition to this novel result, we contribute a thorough analysis of these changes, a discussion of their ethical implications, and proposals for future research to better understand factors affecting changes in children's imaginaries about robots.

2 RELATED WORK

Below, we discuss two types of related research. One set of research asks children to imagine robots, typically through some form of artwork. The other aims to better understand children's perception of robots by asking them questions about robots or obtaining their reaction to robot use scenarios, with a focus on social aspects. A common thread in both sets of research is children's association of robots with human-like characteristics including autonomy (e.g., few references to the ability to control robots), and affective and cognitive abilities (e.g., personalities), as well as a set of biases likely arising from media (e.g., violent male robots) [19], which have concerned some researchers [34].

2.1 Children Imagining Robots

The work presented in this paper is closest to prior research where researchers ask children to imagine robots. These research efforts were intended to gain insights into children's ideas about robots, including stereotypes they may have acquired from media, and in at least one case, to understand the characteristics of robots with which children would like to interact.

Perhaps closest to our work was that of Blancas et al. [32] who worked with a large group of 9-10-year-old children with the goal of learning about children's design preferences for robots with which they would like to interact. As in our study, children were exposed to robots, although during only one session, and designed robots by drawing them and answering questions about them. The authors found that most robots (over 70 percent) were anthropomorphic, which coincided with the design of two of the three robots they saw, but had machine-like features. They also studied the interaction of children's gender and the type of functionality they expected in their robots finding that "defense" robots (e.g., military or police) were the most common type drawn by boys (no girls drew this type of robot) and learning robots the least likely. Girls spread their robots across a variety of functionalities, with the most popular being health and learning. Despite the similarities, our work has many differences including children's ages, the length and type of activities children conducted with robots, and the fact that we asked children to imagine their robots by drawing before and after robot activities.

Other research also analyzed drawings and other artistic depictions of robots imagined by children. The outcomes have been somewhat consistent over time, with themes of anthropomorphization being persistent. This was the case over 20 years ago in the findings by Bumby and Dautenhahn of children anthropomorphizing robots in their physical appearance and abilities while also tending to make them male [9]. Ríos Rincón et al. conducted a more focused activity asking children to imagine robots with which they would like to play. The theme of anthropomorphization in form and function came up again with the addition of the robots having controls and the ability to play games with children [46].

Malinverni et al. discussed issues of anthropomorphization, gender, and violence, as well as the role of media in establishing these stereotypes in their work with 10-11-year-old children [33, 34]. Their imaginaries were developed through workshops in which children got to engage with one type of robot (an Mbot) and develop robot characters to use in a story [34]. The story children developed presented robots as autonomous beings with human-like appearance, affective, and cognitive characteristics [34]. These imagined robots were also mostly engaged in fighting other robots with weapons [34]. When asked, the children said they got their ideas about robots from media [34]. Malinverni et al. turned their concern about the result of the activities they conducted into a call to foster "ethical and critical sensitivity in the use, design, and development of robots" among children [33].

Overall, the consistent finding across all studies on children's imaginaries about robots is the theme of anthropomorphization [9, 32–34, 46]. These human-like forms were associated with human-like affective and cognitive characteristics (including autonomy) [9, 32–34]. In addition, violent robots were present in some of the studies, either drawn by boys or described as being male [32–34].

2.2 Children's Perception of Robots and Robot-Use Scenarios

A related set of research addresses children's perception of robots. One line of work involves learning about children's perceptions before and after programming activities. For example, Williams et al. asked 4-6-year-old children about their perceptions of robots before and after conducting activities where they learned simple artificial intelligence concepts by programming a robot for about one hour [55]. They found that older children and children who learned more about artificial intelligence during the activity were likelier to think robots were closer to people than to toys and less likely to think they were smarter than robots [55]. While not working exclusively with robots, Druga and Ko asked 7-12-year-old children about their perceptions of smart devices (two robots and a voice assistant) before and after conducting artificial intelligence programming activities during three sessions. They found that children were less likely to attribute some human-like characteristics (being able to remember them and being friendly) to the smart devices after the activities [16]. It is interesting how these sets of apparently similar activities appeared to shift children's perception of robots in opposite directions.

Other work, led by Mioduser and colleagues, combines exposure to robots with programming. They conducted a series of studies with small numbers of children to better understand children's perception of robots, of which we highlight two. In the first study, they exposed six kindergarten children to a robot completing increasingly complex tasks, finding that as the robot conducted more complex tasks, children were more likely to provide psychological than technological explanations for its behavior. However, experience programming shifted explanations toward the technology side [31]. In the second study, they worked with six kindergarten children who programmed a robot to respond to events through actions during five 30-45 minute sessions. After the activities, the children used rule-based and mechanistic explanations when asked to explain the robot behavior they developed [38].

Other researchers have studied the effect of exposure to robots on children's perceptions. Beran and Ramírez-Serrano exposed children to an actual robot, in this case, a robotic arm stacking blocks, but asked children about their views on robots only after seeing it in action. Based on the answers to a questionnaire by 198 5-16-year-old children in a museum, the authors reached similar conclusions to those in the studies using artwork, finding that children ascribed cognitive, affective, and behavioral characteristics to robots [51]. Kahn et al., working with 9-15-year-old children, also found that children ascribed human-like characteristics and even moral standing to a robot after interacting with it for 15 minutes [25]. These results are consistent with those of an even larger survey of primary and secondary school students on their perceptions of robots, which concluded that children's exposure to robots in media led them to identify robots with anthropomorphic shapes and human-like cognitive abilities [19]. In Fortunati et al.'s study, the most popular show cited by children was *Transformers* [19], which depicts good and evil robots, who are fully autonomous and have personalities and gender (mostly male), fighting each other [1].

Others conducted similar research focusing on how children perceive and interact with social robots, including interactions with pet-like robots [6] and game-playing robots [14]. In these cases, the goals were not for children to imagine robots, but to understand children's perceptions of social robots after interacting with them. Woods tried to understand social perceptions of different types of robots based on how they looked. She collected the reactions of 9-11-year-old children to 40 robot images, finding that children judged human-like robots as more aggressive and human-machine hybrids as friendlier [57]. A more recent study by Rubegni et al. studied more realistic scenarios for social robots to understand children's reactions to them. In this study with 8-14-year-old children, the authors identified themes of agency, comprehension, socioemotional features, and physicality, with an analysis of children's hopes and fears with respect to each theme [44].

Comparing robots to other entities, Bernstein and Crowley conducted a study with 4-7-year-old children to understand their perspectives toward robots (with examples of a humanoid and a vehicular robot) when compared to perspectives about people, animals, plants, toys, and other computational devices [7]. They found that children attributed similar levels of intelligence to robots and cats, above those they attributed to computers [7]. In addition, they attributed psychological capabilities to robots that were roughly halfway between those of a computer and those of a cat [7].

Overall, the studies on children's perceptions of robots are consistent with children's imaginaries in children often ascribing human-like cognitive and affective abilities to robots [19, 25, 38, 44, 51, 55, 57], or at least, cognitive and affective abilities similar to pets [7]. The evidence on the impact of programming-like activities on children's perception of robots is mixed, with some evidence suggesting these activities cause children to see robots as more machine-like [16, 31, 38], and other evidence pointing in the opposite direction [55]. One study found a consistent theme of violent male robots fighting each other, which they learned was based on depictions of robots in the media [19].

2.3 Importance of Recurring Themes in Children's Views of Robots

Anthropomorphism is the leading theme across prior studies on children's imaginaries and perceptions of robots [9, 19, 25, 32–34, 38, 44, 46, 51, 55, 57]. Malinverni et al. saw anthropomorphization as a way for children to build meaning around the nature and function of robots, which can both limit children's conceptions of robots, but also potentially enable positives such as using robots as avatars to communicate with others [34]. Others have expressed concern about anthropomorphic representations of robots hiding aspects of robots (i.e., how they work) and thus leading to misunderstandings of the nature of interactions between people and robots [18]. Such misunderstandings would not be a good fit for the concept of computational empowerment, as they could limit children's critical engagement with robots [15, 24]. Regardless of one's views on anthropomorphization, its impact on how children and adults relate to and understand robots [58] makes it an important aspect of children's perspectives on robots.

Other recurring themes are closely related to anthropomorphism, such as robots' functions, and issues related to gender and violence. In terms of robotic functions, these may reveal children's views on robots' cognitive and affective characteristics [9, 32, 34], which again are relevant to how children relate to robots and whether they have misunderstandings about the nature of robots. These misunderstandings could include seeing robots as fully autonomous and not under human control [19, 33], which could again conflict with the concept of computational empowerment [15, 24]. Gender aspects have been discussed by a few researchers [19, 32, 34], with a concern that negative gender stereotypes in robots can normalize problematic associations, such as males in violent roles and females in service roles [34]. These concerns are part of broader efforts to make computational thinking activities more gender-inclusive [30].

The best evidence available points at the consistency of children's perception of robots, in particular with regard to anthropomorphism, arising from depictions of robots in children's media [19, 34]. This evidence is consistent with similar evidence suggesting media portrayals of robots affect adults' views [5, 48].

2.4 Research Gaps Inspiring This Study

Prior work leaves important gaps that we sought to contribute to answer through this study. First, there is conflicting evidence on the impact of programming activities on children's perceptions of robots [16, 31, 38, 55]. It would be useful to clarify, through activities similar to what would occur at a school implementing ER curricula, whether such activities would result in children seeing robots as more or human-like or more machine-like. Second, all the research we found reported in English on the topic of children's imaginaries and perceptions of robots originates from Europe, North America, or the Middle East. Research on adults' perceptions of robots provides evidence that these perceptions can change by world region [21, 29, 40], suggesting the need to conduct research on children's perceptions of robots in other regions of the world, such as South America.

3 RESEARCH OBJECTIVE

Our research objective addresses these two gaps. We sought to understand the impact of ER activities implemented in a kindergarten classroom on children's imaginaries about robots in a South American setting. More specifically, we were interested in how the imaginaries changed, while taking into account themes from prior studies, such as anthropomorphism, function, and any gender-related aspects.

4 METHODOLOGY

This study employs a mixed methods approach, combining qualitative thematic analysis and quantitative methods to compare the frequency of each theme's emergence in children's drawings. Moreover, it explores children's imaginaries through drawings at two points in time (before and after ER sessions) to capture possible changes. We based our methods on prior research on children's imaginaries with respect to robots [9, 32–34, 46] while going beyond prior studies by asking for children's imaginaries before and after conducting 15 ER sessions. Note that the total amount of time spent with children during these ER sessions is well within the range of prior ER activities for kindergarten children [3]. In other words, the length of the activities reflect what an implementation of ER may look like in a kindergarten classroom. We conducted these ER activities between May and October of 2022 in a public school in Montevideo, Uruguay. The ER activities were aimed at exploring the usability and feasibility of different robots for preschoolers in a classroom setting. The public school curriculum in the country where the study was conducted calls for computational thinking education at the kindergarten level, but the call lacks specifics and has yet to be implemented. We conducted the ER activities in this context, with robots being considered for the implementation of computational thinking activities at the kindergarten level.

The unusual context of having consistent results on children's imaginaries about robots across decades, geographies, and age groups convinced us that having all participating children create their imaginaries before and after the ER activities was the correct next step in research. Without such consistency of results, a control group would have been necessary to rule out external factors affecting children's imaginaries.

4.1 Participants

Three classrooms from a public kindergarten (children aged 5-6-year-old) in Montevideo, Uruguay participated in the activities. The data analyzed in this paper corresponds to only two classrooms. The third had to be discarded as the second instance of drawing robots was strongly influenced by the group's teacher who asked

Table 1: Children that participated in each drawing session.

Drawing session	Participants	Absent
Before ER	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12, P13, P14, P15, P16, P17, P18, P19, P20, P21, P22, P23, P24, P25, P26, P27	P28, P29, P30
After ER	P1, P2, P3, P5, P6, P8, P9, P10, P11, P12, P13, P14, P15, P16, P17, P18, P19, P20, P21, P22, P23, P24, P25, P26, P28, P29, P30	P4, P7, P27

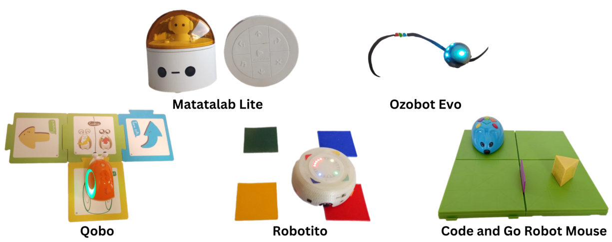

Figure 2: Robots used in ER sessions.

children to draw how the robots were controlled and made it impossible to observe one of the issues that we wanted to analyze: the spontaneous inclusion of human control elements in the drawings.

In the remaining two classrooms, we worked with 30 children in total (13 girls and 17 boys): 27 children (12 girls and 15 boys) in the first drawing activity and 27 children (11 girls and 16 boys) in the second drawing activity (see Table 1). Twenty-four children (10 girls and 14 boys) participated in both instances.

The study protocol was approved by the Ethics Board of the lead institution, and we obtained informed consent from parents or caregivers. We provided children's parents or caregivers with detailed information about the study, analysis, and future usage of the collected data. We invited children to participate in our activities, but children decided how engaged (or not) they wanted to be. All methods were in accordance with the Declaration of Helsinki [2].

4.2 Procedure and Materials

Between May and October of 2022, we conducted 15 sessions that included diverse ER activities (see Table 2). We conducted drawing activities before the first and after the last ER session, for a total of 17 sessions with children.

4.2.1 Robots. During the ER sessions, the children got to work with five different robots: control remote operated Matatalab Lite [36], a robot that uses tangible coding cards Qobo [43], omnidirectional robot Robotito that senses color patches on the floor [52], three Ozobots [41] (two Ozobots Bit and one Ozobot Evo) that follow black lines and react to color codes, and Code & Go Robot Mouse [28] programmed using physical buttons on its back (see Figure 2). With each robot, the activities included robot presentation and exploration, and problem-solving-based activities (see Table 2).

The robots were selected based on considerations for potential implementations in public schools involving issues such as age-appropriateness, cost, and availability, while also enabling us to explore different types of programming interfaces for preschoolers. The robots have designs typical of robots used in ER activities with young children [3] and the activities we conducted with them are also typical of prior ER activities for kindergarten children reported in the literature [3].

4.2.2 Researchers and Teachers' Role. Each session took between 30 minutes and 1 hour, depending on whether we worked with two classroom groups together (longer sessions) or with just one at a time, and was typically led by 1 to 2 researchers. Classroom teachers normally used the session time to prepare material for after-session curricular activities, but they always helped the researchers with classroom management (assigning children to groups, preventing inappropriate behaviors, etc.). The classroom teachers led only one session (#4). We were unable to conduct sessions weekly due to scheduling conflicts with meetings between the principal and teachers, school activities, and pandemic-related issues.

4.3 Data Collection and Analysis

We collected data twice. The first occasion was in May before children experienced ER sessions and the other in December, after the ER activities had been completed. Three researchers participated in the data collection process. Two in the first drawing activity (R1, R2) and two in the second (R1, R3).

First, the researchers introduced themselves and after some ice-breaking questions, children were handed paper and color markers and asked to draw what they imagined a robot to be like. They were given about 15 minutes to draw. After they finished drawing, we conducted a "show-and-tell" activity in which they explained the functionalities and characteristics of the robot they had drawn to the researchers. A small number of children (four in the first session) opted not to participate in the show-and-tell activity but did participate in drawing the robot, and took part in the robotics activities later on. In this case, only their drawings were analyzed. Collected raw data include pictures of the children's drawings (see Auxiliary Material) as well as video recordings of each child's explanation of the robot they drew.

Three researchers participated in coding the drawings and data extraction from video recordings, employing a mixed coding approach. Two (R1, R2) analyzed and coded all the material related to the first drawing session, and two (R1, R3), all the material from the second session (i.e., each robot drawing and description was independently coded by two researchers). We employed thematic analyses to identify recurring patterns and themes within the drawings and children's oral descriptions of their drawings, using a well-established six-step approach [8]: familiarization with data; creation of initial codes; searching for themes; reviewing themes; defining themes; final analysis. We developed the first codebook inductively, creating data-driven codes. This process resulted in three categories: the form/shape of the robot (animal, humanoid, indistinct, machine, or plant), robotic-related features (antenna,

Table 2: Summary of the drawing activities and 15 ER sessions.

Session	Robot	Date	Activity description
Drawing	-	19.05.22	Drawing robots and presenting the drawings.
#1	Matatalab Lite	26.05.22	Presenting homemade robots (crafting robots at home based on drawings from school) and getting to know remote-control operated robot Matatalab Lite.
#2	Matatalab Lite, Qobo	02.06.22	Unplugged activity "playing to be robots", interacting with Matatalab Lite, exploring Qobo robot and its tangible cards (forward, turn right, turn left, color change, dance, conditional turning cards).
#3	Qobo	09.06.22	Exploring "fun cards" (train sound, water, jiggles, dice) and preparing programs using all cards.
#4	-	30.06.22	Session led by the class teachers. Unplugged activity using a paper map and Qobo paper coding cards based on preparing a tangible path from the start to the end card.
#5	Qobo	07.07.22	Executing the programs prepared on paper with the real robot.
#6	Robotito	21.07.22	Exploring Robotito and color cards used for programming.
#7	Robotito	28.07.22	Programming paths and avoiding obstacles using Robotito.
#8	-	04.08.22	Visiting College of Engineering.
#9	-	11.08.22	Drawing new ideas for Robotito.
#10	Ozobots	08.09.22	Exploring Ozobot and its color codes.
#11	Ozobots	19.09.22	Drawing paths for Ozobot and putting stickers with color codes on the paths.
#12	Ozobots	29.09.22	Predicting where Ozobot will go using paper maps with printed color codes and validating the prediction using the robot.
#13	Code and Go Robot Mouse	13.10.22	Exploring the Code and Go Robot Mouse.
#14	Code and Go Robot Mouse	20.10.22	Planning the route from the initial point to the cheese on paper and executing the program using the robot.
#15	Code and Go Robot Mouse	27.10.22	Planning the route from the initial point to the cheese on paper and executing the program using the robot.
Drawing	-	01.12.22	Drawing robots and presenting the drawings.

batteries, buttons, remote control, wheels), and function (ludic and social activities, non-specialized activities, professional).

Subsequently, we supplemented the codebook deductively, incorporating codes from relevant literature, as suggested by Gioia [20]. This addition introduced three new categories: violence (present or not), gender (female, male, or gender-neutral), and human control (autonomous, dependent, mixed, no data). We coded the gender based on the drawings, the names children gave their robots, and verbal descriptions. To identify control elements, we looked for the existence of buttons or remote controls in the drawings and the verbal descriptions of the robots. In addition, in the second drawing session, we asked children how the robot knows what to do, which sometimes resulted in children spontaneously describing how they would control the robot. We asked this question at the end of show-and-tell to ensure it had no impact on what they drew or what they said beforehand.

Each researcher independently extracted relevant codes into a spreadsheet, with each drawing and description having codes extracted by two researchers. After extracting codes individually, researchers compared their extracted codes. If the two coders responsible for coding a session could not reach an agreement, the third coder was asked to be a tie-breaker. Researchers then went through another round of thematic analysis [8]. After each theme had a coherent pattern, they were added onto a thematic map in an online collaborative whiteboard [39] that adequately captured our coded data.

We used extracted codes to assign categories to each imagined robot under form/shape, robotic-related features, control elements, robot's functions, gender, violence, and human control (e.g., an anthropomorphic robot, with buttons, that cooks, is male, not violent, dependent). To identify statistically significant changes between children's ideas of robots before and after ER activities, we used McNemar's test, using only data from the 24 children who participated in both instances. McNemar's test is appropriate for comparing matched groups when the dependent variable is categorical [12].

5 RESULTS

We organize the results in the following sections: representation of form and robotic-related features, functionalities and activities of the children's imaginary robots, changes in individual children's imaginaries and lastly, presence of violence in children's imaginary robots.

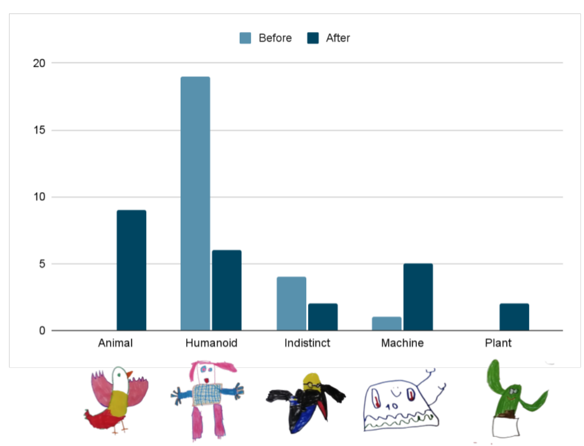

Figure 3: Frequency of children's imaginary robots' forms in their drawings before and after the ER sessions.

5.1 Representation of Form and Robotic-Related Features

We observed that before the ER sessions, children gave their robots a predominantly biped humanoid robot form (n=19). There was only one example of a machine-shaped robot and 4 of an indistinct form. After the ER sessions, children's imaginary robots took a wider variety of forms, including animal (n=9), machine (n=5), humanoid (n=6), plant (n=2), or indistinct (n=2) (see Figure 3). Statistical analysis of this aspect revealed a statistically significant shift from predominantly humanoid to non-humanoid representations (x^2(1, N=24)=11.077, p<.001).

After the children experienced the ER sessions, we observed that the drawing of their imaginary robot included more robotic features than before the ER sessions (see Figure 4). For this study, we define robotic features as the characteristics and attributes that directly contribute to a robot's functionality and operation. Batteries provide the necessary electrical power for the robot's movement and activities. Wheels enable mobility, which is a key characteristic of many (educational) robots. Buttons, remote controls, and antennas serve as interfaces for controlling and communicating with the robot. Our results indicate that, while 10 children drew buttons, wheels, or antennas before ER activities, after these activities, 15 children drew robotic features, and these became more diverse (5 features vs 3 features). After experiencing ER sessions, children drew more remote controls, batteries, and wheels, and fewer antennas. The number of buttons in the drawing remained the same, although remote controls included buttons. This can be related to the fact that these elements are needed to make a robot work (batteries and wheels) and that a user interface is also needed to control the robot (remote control and buttons).

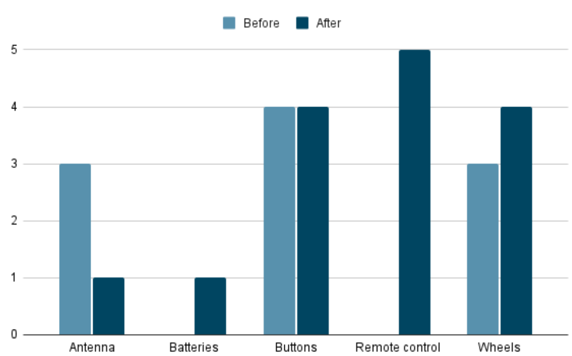

Figure 4: Frequency of robotic features in children's drawings before and after ER activities.

5.2 Functionalities and Activities of Children's Imaginary Robots

We analyzed children's explanations of the drawings and categorized the data into three categories related to their imaginary robots' functions or characteristics: useful and specialized work or profession (e.g., cooking, spying), non-specialized activity (e.g., ability to fly, jumping high), and ludic and social activities (e.g., playing games, watching YouTube). The ratios between the categories remained similar before and after ER activities, but there was a trend toward children drawing and describing robots with multiple functionalities after ER activities (more on this trend is discussed under section 5.3). Some robots performed many diverse activities, for example, one child drew a robot that cooks, swims, and can fly to the sky. In those cases the actions were tagged in multiple categories - in the mentioned example as: useful and specialized work or profession (cooking) and non-specialized activity (swimming and ability to fly).

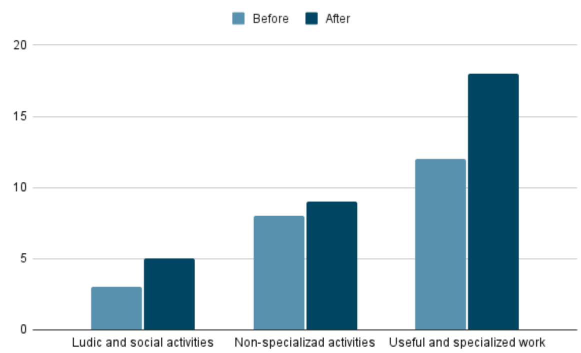

Figure 5: Classification of robots' functionalities and activities before and after ER sessions.

Across both drawing sessions, we found that most of the children gave their robots useful and specialized work or professions (n=30). The most common task or profession was cooking (cooking in general or specifically making pizza or pancakes) (n=16). The second most common work or profession was related to house cleaning and sorting and organizing toys (n=4). Children also mentioned that their robot could provide light and open bottles, turn on the TV, bring water, stretch its arms to reach things that are far away, measure the temperature, help in trips to other countries, make buildings, and cut blocks in half. Also, three children mentioned that their robots were spies and that they looked at what people do. One had the form of a cactus, so people would not be aware it was a spy. One child drew a superhero robot and explained: "Superhero robot, it knows how to jump, fly, it has turboprops below, jumps over buildings, makes force fields, has all the powers in the world". Children mentioned and drew more useful and specialized work and professions (n=18) after ER sessions than before (n=12), as shown in Figure 5.

Considering the category of non-specialized activity, the most common activities were flying (n=4) and jumping (n=2). Another characteristic was the ability of the robot to transform itself (n=2). For instance, one child said "It attracts everything that is yellow. It transforms into a skateboard". Exceptionally, one child mentioned that he did not know what his robot did after the ER sessions, while before the sessions, he drew a robot to "help when traveling to countries, stretch its arms to reach things that are far away". Children mentioned almost the same number of non-specialized activities before ER activities (n=8) and after (n=9), (see Figure 5).

Table 3: Changes in robot functionalities and activities across categories, comparing pre-ER activity categories (left column) with post-ER activity categories (top row).

Before ER / After ER	Professional	Ludic	Non-specialized	Multi-category
Professional	7	0	2	2
Ludic	2	0	0	1
Non-specialized	2	0	2	3
Multi-category	1	0	0	0

The third category, ludic and social activities, included ludic activities such as watching YouTube, generating rainbows, playing, and dancing. For the social activities, some children mentioned that their robots give hugs, and one mentioned "it does not have a particular function; it was made to be taken care of by other people. It has laser eyes and raises its tail". Also, another child mentioned that the robot's function was to be a friend, while another child said that the robot plays with other children. We also observed children presenting slightly fewer social and ludic activities with their imaginary robot before than after the ER sessions (n=3 vs n=5).

5.3 Changes in Individual Children's Imaginaries

We compared each child's drawing from both sessions to observe the changes in the type of activities the robots performed. Twenty-four children participated in both drawing instances, but in the first session, two decided not to describe their drawings. The changes for the remaining 22 children are summarized in Table 3.

For this analysis, we worked with the categories described in the previous section and added one new option: multi-category. We used the multi-category tag for robots that combine more than one category, for example a robot that organizes toys (useful and specialized work or professions category), gives hugs (ludic and social activities), and flies (non-specialized activity category).

Initially, half of the children drew robots that were classified as having useful and specialized work or professions. After ER activities, most of them (n=7) also drew robots from the same category, but two drew robots performing non-specialized activities (one robot that jumps and one that does not have a specific function), and the other two drew multi-category robots. Three children who initially drew ludic robots changed to robots with useful and specialized work or professions (n=2) and multi-category (n=1) robots. Of seven children who in the first session drew robots performing non-specialized activities, two remained in the same category after ER activities, two changed to robots that perform useful and specialized work or professions, and three to multi-category robots. Note that during the second drawing session, no robots fit the ludic and social activities category alone, but instead five of the multi-category robots included this category.

All the multi-category robots (n=1 in the first and n=6 in the second session) had at least one activity classified as specialized work or profession.

5.4 Representation of Gender in Children's Imaginary Robots

Regarding the presence of gender in children's imaginary robots, we also observed a change, as robots drawn before the ER sessions were more likely to have a defined gender than those drawn after the sessions. Specifically, before the ER sessions, children's drawings and explanations indicated eight male robots, five female robots, and 11 gender-neutral robots. In contrast, after the ER sessions, we found that only one child had assigned a gender to their robot. Many of the children expressed the gender of their robot by giving it a name that sometimes coincided with their own name or a classmate's. One child specifically alluded to their robot having genitals before the ER sessions. The analysis of the drawings of 24 children who took part in both sessions showed that the change toward gender-neutrality was statistically significant ($x^2(1, N=24)=8.643$, $p<.002$). This change might be linked to the previously mentioned change in the design of the robot's shape. Children drew fewer humanoid robots after the ER activities, which could be related to the lack of gender assigned to non-humanoid robots. Interestingly, before the ER sessions, girls created both male and female robots and some gender-neutral robots, while boys created only boy or gender-neutral robots. After the ER sessions, children increased their depiction of gender-neutral robots.

5.5 Presence of Violence in Children's Imaginary Robots

Violent imagery in children's depiction or description of the robots they created was practically non-existent. In our first drawing session, one child described his robot as being able to use an alarm on its head as well as movement to chase "in case there's a burglar inside the house, it can run after them and catch them" to which one of his classmates asked whether it is a policeman robot and he agreed. It is noteworthy that despite the child giving his robot the ability to chase after and alert about the presence of burglars, no weapons were present in his drawing. In the same session, another child described his robot as being a policeman as well and his drawing shows a robot with large hands and stretched-out arms in order to catch its targets, but no weapons. A third child created a robot that incorporated a saw, a hammer, a stick with sharp teeth, and the ability to cut objects: "My robot also has an alarm, he serves the same purpose and he also has a saw (...) he can cut pieces in half (...) right here [pointing], it has a hammer to construct buildings, and down here [pointing] it has two wrenches". Despite the presence of sharp objects, the child designed these as tools for a builder robot.

In the drawing session after the ER activities, as noted in section 5.2, one child created a "superhero robot". This superhero robot did have a sword, however the child described the sword as a way to control the robot remotely. He also incorporated protective powers such as having the ability to create a "force field around it". All of the robots classified in the "machine" category were dedicated to peaceful activities. Specifically, children gave their machine robots abilities including flying, jumping, making pizza, playing, dancing, controlling rainbows, and measuring temperature. Thus, we did not observe the presence of violent imagery in children's creations before or after the ER sessions.

6 DISCUSSION

6.1 Before ER Activities, Imaginaries Consistent with Prior Research

We explored children's imaginaries about robots before and after children experienced activities with a variety of robots over 15 sessions. Children's imaginaries prior to conducting ER activities were broadly consistent with prior research (for more detail see Section 2), suggesting the South American setting did not result in different imaginaries. Before ER activities, the overwhelming majority of robots children drew had anthropomorphic characteristics, which was the most consistent theme in prior research [9, 32, 34, 46]. This theme went along with only a few children drawing machine-like features, such as batteries or wheels, and very few drawing features that would imply the ability for humans to control the robot (e.g., a remote control). As in prior research, children also gave many of their robots a gender, although they did so to a lesser degree than children in prior research, with the gender of the robot having a close association with the gender of the child. One notable difference with some prior research findings [33] is that children did not seem to associate robots with violence, which could be related to the younger age of participating children when compared to children who participated in prior research. It could be that the media regarding robots that young children experience involves less violence.

6.2 A Significant Shift in Imaginaries After ER Activities

One of the clearest changes in the drawings after the ER activities, reaching statistical significance, was the shift from anthropomorphic representations of robots to a wide range of forms. These included machines, but also plants and animals. This was a significant departure from prior research findings and something different from most robot portrayals in media consumed by children [19]. Note that given the study's location it would have been very unlikely for children to encounter robots outside our activities, so we assume their ideas prior to the activities came from media. In this sense, it appears that the ER activities may have opened up children's imaginations to the forms that robots may take, moving beyond the traditional emphasis on humanoid attributes. It is also possible that in understanding how to conduct basic programming of robots, they also understood that robots are not like humans. Related to the significant reduction in anthropomorphism was the almost complete absence of gender in the robots imagined after ER activities, another statistically significant change. This sharp shift is a clear departure from results in prior research and media depictions of robots. Using gender-neutral robots during ER activities may have also impacted this change.

A more subtle change involved having more children featuring robot components for human control, such as buttons and remote controls (from 4 to 9 children in our sample). In addition, after the ER sessions, we asked children how the robot would know what to do. When we asked this question, 16 out of 24 children said they would somehow control the robot. We believe this is a very important trend as it suggests that the ER activities may have helped most of the children understand that they could control robots, with these children then choosing to design robots they could control. Seeing technology as something to control as opposed to something fully autonomous or that is used to control people is a relevant value to consider.

We also noted increased descriptions of robots that supported multiple types of tasks (1 before ER activities, 6 after). This trend suggests greater maturity in children's understanding of robots, with some children realizing that the same robots could be controlled or programmed to perform multiple types of activities.

A study published by Rudenko et al. after we conducted ours found similar, albeit smaller changes in kindergarten children's imaginaries after children experienced demonstrations of real robots [45]. The children again started with very anthropomorphic representations before the demonstrations, but after the demonstrations, reduced human-like attributes while increasing mechanical ones [45]. Together, our experience and Rudenko et al.'s [45] suggest that exposure to real robots, whether through programming or demonstrations, can lead to similar changes in children's imaginaries about robots, moving them away from anthropomorphic views. Educational activities could therefore be used to bring about similar changes.

6.3 Ethical Implications

Our study provides evidence suggesting that ER activities may help children obtain an understanding of robots as machines humans can control rather than fully autonomous beings. These perceptions went hand-in-hand with children becoming less likely to give robots human-like appearances, which have been associated with views of robots as having human-like affective and cognitive characteristics [9, 27, 32, 34]. We propose that the understanding of robots as machines humans can control in children's imaginaries makes the imaginaries more ethical, as they reflect children having a more informed understanding of a technology that may play a non-trivial role in their future lives. We expect this better understanding of technology to be an important aspect of being well-informed citizens in democratic societies, enabling both creative and critical engagement with technology [15, 24], consistent with the call for computing education goals to encompass citizenship and civic life [54] and societal impacts [26, 53].

Not everyone agrees with our perspective on the positives of avoiding anthropomorphic views of robots. In fact, the ethics of anthropomorphic representations of advanced technologies are a controversial topic. Closer to our perspective, Salles et al., for example, note that anthropomorphic perspectives can limit views on what is possible with novel technologies through a human-centric ontology [47], therefore compromising creativity. They are also concerned about these perspectives leading the public to have misleading views on what novel technologies are and what they are capable of doing, including considering them autonomous moral agents [47], potentially limiting critical perspectives. Researchers in the social robotics space tend to have a different view. Damiano and Dumouchel argue that anthropomorphism facilitates interactions with robots, making it easier for people to interact and feel comfortable with them [13]. They propose instead to focus the ethics of social robots on the outcomes that emerge from human-robot interaction [13]. We do not necessarily see these two perspectives as mutually exclusive. We believe that if users have a solid understanding of robots as machines humans can control, then it is possible they can take advantage of easier interactions with robots with human-like appearances without these interactions changing their views on robots' affective or cognitive characteristics. In other words, activities like those presented in this paper could potentially enable interactions with robots with human-like appearances without compromising perceptions of robots, the kinds of robots that could be created, or critical perspectives about robots. This potential should be tested in future research.

A solid understanding of technology is also a distinctive component of the concept of computational empowerment [10, 15, 24]. In adopting computational empowerment, the Danish curriculum for technology comprehension states that "a technologically founded understanding of technology is a prerequisite for being able to contribute constructively and actively in the development of relationships, communities and societies" [37]. As discussed by Smith et al. [10], the Danish curriculum and the concept of computational empowerment have deep roots in Scandinavian Participatory Design ideals of emancipation, democracy, and quality [17, 23]. With respect to these ideals, ER activities that result in more children seeing themselves controlling robots would contribute to the ideal of democracy [23] and potentially emancipation [23]. In other words, control over technologies reduces or eliminates the likelihood of being oppressed by them (emancipation) [23] and gives those who interact with them a say in what technologies do (democracy) [23]. While links to the quality ideal are less clear, we did note a small trend toward robots who were in some sort of service role, the most popular being cooking, which, combined with greater control, echoes Ehn's perspective of quality as technologies fully controlled by users [17]. Most importantly, from a participatory design perspective, the ER activities appeared to enable children to contribute their own ideas about robots based on a better understanding of the technology, rather than mirroring media portrayals of robots with human-like cognitive and affective characteristics [19, 34]. The robots they imagined after ER activities did not resemble the ones they used in the activities in form or functionality, but took a variety of forms and functions, suggesting that if these children were to take part in participatory design activities, they would contribute their own informed ideas.

Overall, the results were encouraging in that exposure to robots with limited functionality, which are typical of programmable robots for this age group, did not limit children's imaginations as to potential robot capabilities. Rather, the lesson children may have learned was about the nature of robots as programmable machines, rather than machines limited to the functionalities they experienced. While these lessons were not set out as learning objectives for the activities we conducted, they could be more explicitly incorporated into future activities. If similar activities were to be conducted with older children, there could also be opportunities to better understand how they impact children's critical reflection and perspectives on technologies.

7 LIMITATIONS AND FUTURE WORK

A limitation of the work is that we did not have a control group that was not exposed to ER activities with robots. Under different circumstances, not having a control group would mean that we would have little idea as to why the changes in children's imaginaries occurred. What is different about the context of this work is that, as presented under section 2, there is evidence from multiple locations around the world, with children of different ages, of consistent views and imaginaries from children about robots. These most likely arise from media portrayals of robots [19]. Hence, any changes in these imaginaries after an activity to something different are most likely due to the activity and not to other unrelated activities in the classroom or some other form of maturation. In our case, children's imaginaries prior to ER activities were consistent with prior research, but those afterward were clearly different. This study opens the doors to future ones including larger scale studies including control groups. Future studies could be designed to better understand the number and frequency of ER sessions necessary to achieve results similar to those in this study. Such studies could also be designed to follow children after the activities are completed to see for how long their imaginaries about robots remain stable and how they evolve. It would be useful to know, for example, if continuing activities could result in more children imagining robots with explicit forms of human control. Since our ER activities were unusual in using multiple robots, it would also be fruitful to conduct a similar study using only one robot to see if it results in similar changes in imaginaries about robots. Finally, based on the results of the studies suggested above, a larger study could be designed including multiple schools and controls, which could inform broader implementations of ER activities. Such a study would also be ideally led by teachers, better reflecting what ER activities may look like in a kindergarten classroom, and avoiding any potential impact the introduction of researchers may have.

Another potential limitation was that during the first "show and tell" activity, the children described their robots in front of the whole group (two classes together). While listening to their peers' presentations could have influenced children who presented later in the session, we did not find evidence of such an influence (i.e., a robot characteristic being picked up by multiple children). We believe that drawing the robots before presenting them helped children to focus on their own ideas and not to copy those of others. We observed that five children included cooking as an activity of their robots, which could have been due to the school's Principal mentioning before the activity that she would like a robot that cooks. Although she did not make the same comment before the second drawing session, which occurred several months later, 11 children mentioned that their robots cook. As cooking seems to be a task that appears spontaneously in children's descriptions, we decided not to exclude this task from our analysis.

8 CONCLUSION

As children grow up in a society where computing is increasingly ubiquitous, it is important that they gain an honest and accurate understanding of the nature of technologies, including those that are portrayed as intelligent. We believe such an understanding is of great importance to children being well-informed citizens, which in turn is crucial to the functioning of democratic societies, and being able to engage with technology in a creative and critical manner. In this paper, we provided evidence suggesting that ER activities in the classroom may change kindergarten children's perspectives on robots, moving them away from anthropomorphic views that often involve human-like cognitive and affective characteristics and toward a factual understanding of their nature. This more factual understanding involves realizing that robots are unlike people, can take many different forms, can serve people in multiple ways, and can be controlled by people.

9 SELECTION AND PARTICIPATION OF CHILDREN

The study protocol was approved by the Ethics Board of the lead institution. We obtained informed consent from parents or caregivers. We provided children's parents or caregivers with detailed information about the study, analysis and future usage of the collected data. They were also encouraged to contact the main researcher if they had any questions or comments about it. We invited children to participate in our activities, but children decided how engaged (or not) they wanted to be. All methods were in accordance with the Declaration of Helsinki [2].

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