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Promoting Children's Critical Thinking Towards Robotics through Robot Deception

Lupetti, Maria Luce; Van Mechelen, Maarten

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Promoting Children´s Critical Thinking Towards Robotics through Robot Deception

Maria Luce Lupetti
Faculty of Industrial Design Engineering
Delft University of Technology
Delft, The Netherlands
m.l.lupetti@tudelft.nl

Maarten van Mechelen
Center for Computational Thinking and Design
Aarhus University
Aarhus, Denmark
mvanmechelen@cc.au.dk

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***Abstract*— The need for critically reflecting on the deceptive nature of advanced technologies, such as social robots, is urging academia and civil society to rethink education and the skills needed by future generations. The promotion of critical thinking, however, remains largely unaddressed within the field of educational robotics. To address this gap and question if and how robots can be used to promote critical thinking in young children's education, we conducted an explorative design study named Bringing Shybo Home. Through this study, in which a robot was used as a springboard for debate with twenty 8- to 9-year-old children at school, we exemplify how the deceptive nature of robots, if embraced and magnified in order for it to become explicitly controversial, can be used to nurture children's critical mindset.**

***Keywords*— deception; societal impact; critical thinking; design exploration; educational robotics.**

I. Introduction

Assessing the validity and truthfulness of information and, by extension, any form of cultural production, is a constant challenge in our digitized society. When confronted with novel and emergent technologies (e.g., autonomous driving, social robots for healthcare), for instance, people often find it difficult to fully grasp how these technologies work and what their capabilities are. Especially when these technologies are accompanied with subtle and persuasive narratives about their potential, there may be a risk for deception [1]. More so, since the complexity of technologies that people are exposed to on a daily basis is constantly increasing, developing a critical understanding of their inner workings and impacts has become an arduous task.

Robots, in this regard, represent a particularly controversial type of technology. They differ from other types of technological things for their lifelike abilities and apparent capacity to engage in human-like relationships [2]. Successful human-robot interactions often result from deceiving people into thinking that robots have the ability to understand the world around them, and hence, that people can establish genuine relationships with them over time [2]. Especially when intended to operate in everyday environments robots are often designed to evoke social interactions that are quite similar to 'human' social interactions in order to ease communication with their human counterparts [2]. One of the possible consequences of this – apparently innocent – form of deception is that people tend to overestimate robots' ability to understand the world and situations, and consequently delegate decisions and actions that would significantly impact the quality of human life [3]. This problem is even more prominent if we think about vulnerable groups as the elderly and children [4]. A child may be lured into an illusory relationship with robots, which could result in emotional and psychological effects in the long haul [4; 5; 6]. As [3] argue, a prolonged exposure of children to social robots with caring duties could interfere with the formation of secure attachments and could cause children to miss out on the give and take of human-human relationships. In educational contexts too, exposure to a robot performing the role of a teacher may be wrongfully attributed to high abilities by children, such as the capacity of care, which may lead to undesirable forms of attachment [6]. Further, in the context of children's toys, children have shown to ascribe human and life-like qualities to inanimate objects like robots and 'connected' toys, including cognitive, behavioral and affective characteristics [7; 8; 9; 10]. Especially when provided with conversational abilities, robotic toys may give children the illusion of a genuine social experience, while the robot's answers are in fact designed by a company to encourage specific consumption objectives [11].

The challenge of properly interpreting technology and, in the case of social robots, its deceptive characteristics, together with the growing complexity of society at large, is urging academia and civil society to rethink what skills people will need in the future and how the educational system can promote them (e.g., [12; 13]). In particular, there is a growing call for initiatives and approaches that promote *critical thinking* skills [14; 15; 16; 17; 18] that enable future citizens to deal with the complex nature of emergent technology and develop a critical understanding of the dominant narratives and claims surrounding it. However, despite being a prominent and popular topic for more than a decade now (see the discourse surrounding 21st century skills [19; 20; 21; 22]), examples of educational robotics applied to promote critical thinking are still limited [23]. Therefore, in this work we investigate what might be a meaningful way of introducing social robots in an educational context for nurturing children with a critical mindset towards technology, as an alternative to using social robots as teachers or peer learners. Specifically, we explored the questions: *how can a robot foster critical thinking and, specifically, reflections on what technologies like robots can do and how they relate to us?*

We explored these questions through the development of '*Bringing Shybo Home*': a playful learning experience run in the uncontrolled environment of a primary school class. Inspired by the Philosophy for Children approach [24], we used a low-anthropomorphic robot as a character of a story to invite children, aged 8 to 9, to collectively analyze the robot, make hypotheses about its abilities, and test them with the support of dedicated materials. We purposefully introduced the robot in a deceptive manner with the aim to understand if the deceptive

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nature of social robots could in itself be used to trigger reflection and develop a critical understanding of this emergent technology. Based on observations of children's behavior and transcripts of their discussions during the activity, we claim that even a simple robot like Shybo, if contextualized in a story and used as springboard for debate, can generate rich and varied discussions between children, resulting in an exchange of diverging opinions about the nature of robots and their abilities, which we deem crucial for critical thinking. The main contribution of our work, then, is to provide human-robot interaction (HRI) designers with a conceptual provocation grounded in empirical evidence: *embrace and magnify robot aspects with deceptive potential, as personality and intentionality, so that they become explicitly controversial and may be used as springboard for debate.*

II. Related Works

The use of robots for fostering critical thinking in the educational environment is still very limited. To support this claim, in this section we provide an overview of the main types of applications and roles of *robots for learning*. Since our aim is not to move a critique to current approaches to educational robotics, rather unveil an underexplored design space, we also provide an overview of experiences and literature dedicated to learning critical thinking which, we believe, could be a valid source of inspiration for the field of educational robotics.

A. Robots for learning

Educational robots and related activities demonstrated to be highly engaging, motivating and powerful in promoting problem solving skills and teamwork [25]. They have grown in popularity over the last decades, especially for supporting science, technology, engineering and mathematics (STEM) education [25]. And, while the use of educational robots started with the primary intent of supporting the teaching of computer programming, it extended over time to include a broader set of computer science concepts and skills, which are commonly addressed under the umbrella term of computational thinking skills [25; 26; 27; 28]. To this end, these artefacts have been used in various modalities, such as instructional materials, learning companions and teaching assistants [25]. In this regard, [29] provided a useful distinction that focuses on the relationship we can find between robotics and education: *robots as educational foci* and *robots as educational collaborators*. In the first case, robotics and the development of a robot are the explicit goal of the educational experience and the student-robot relationship is the one of creator-creation. In the second case, fully developed robots are employed as members of the learning ecosystem and the student-robot relationship may vary from peers and companions to collaborators.

The activities carried out with educational robots can also vary in nature. [30] suggests that these can be divided in three main approaches: a theme-based curriculum approach, where 'curriculum areas are integrated around a special topic for learning and studied mostly through inquiry and communication'; a project-based approach, where 'students work in groups to explore real-world problems'; and a goal-oriented approach, where 'children compete in challenges in Robotics Tournaments taking place mostly out of school'. Although all three approaches have proven to be successful in enthusiastically engaging students and supporting them in achieving learning goals, obstacles to systematically implement robotics as an integral part of school curriculum still exist [31]. These include the time-consuming nature of the activities, the costs of equipment and the amount of additional practical work and novel skills required from teachers [31; 32]. On a more strategic level, current approaches to educational robotics also present weaknesses as their focus mostly remains on developing *technical competences* through 'scripted experiences where students are guided through a 'recipe-style' discovery of predefined concepts' [33]. While such focus on technical competence may be a valuable learning for the ones who will pursue a future career in engineering and science work, current societal developments call for a shift in educational technology from technical skills towards *technological and computational fluency or literacy* [31]. This would imply knowledge, skills and attitudes valuable for all citizens, enabling them to not only operate but also design and critically reflect on digital technologies that are increasingly pervading our society [34; 35]. As emerging from current discussions surrounding the so-called 21st Century skills [16] and the need for education systems to revise themselves, educational robotics should also extend its scope beyond supporting the teaching of subjects that are closely related to the robotics field [36] to include transversal competences such as critical thinking, problem solving, creativity, teamwork and communication skills [31]. In Alimisis words: "Educational robotics should be seen as a tool to foster essential life skills (cognitive and personal development, team working) through which people can develop their potential to use their imagination, to express themselves and make original and valued choices in their lives" [31]. Up today, this largely remains an underexplored territory in HRI research (see [23] and [37] for examples of educational robotics and critical). And even the few existing examples do not specifically explore how a robot itself could be both the technology under critique as well as the means to carry out the critique. Thus, we believe there is a broad HRI design space to explore, on how robots could be used in educational settings to support the development of non-technical skills needed in society, above all critical thinking.

B. Learning critical thinking

There is no consensus definition of critical thinking [38], yet it is generally recognized as a type of thinking that 'doubts methodically', as it is the 'examination of a principle or a fact, for the purpose of making an appreciative judgment of this principle or fact' (Lalande, 1991 as cited in [38]). As explained by [39] critical thinking is a learning process where one has to engage and evaluate with pros and cons of a given topic, as a way to establish a truth, to transform information and generate new ideas. Due to this reflective nature, critical thinking is claimed as one of the fundamental skills for the 21st century society [16] where people are surrounded by, and need to deal with, claims that they have no means to verify directly [1]. As Conrad Hughes argues: "We are living in a world of sound bites, bandwagons, fads, over-simplifications and misinformation. This takes place in the spectra of politics, social media and vested financial interests that dominate many information fields. […] Doubting sources, scrutinizing arguments, seeking robust evidence to claims and identifying ideological biases behind assumptions is more important than ever, especially since there is a coarsening of political discourse, an intensification of

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polarized and even extremist positions, and much crass persuasive argument at work" [40].

Despite critical and creative thinking have been recently become central topics in the discourses about skills needed in contemporary society (e.g. [12; 13]), their importance is not new to education literature [16]. Already in the 60's, the importance of promoting critical thinking, also addressed as 'good thinking' [41], in formal education was the subject of lively debates. In those years, [42] argued for what now we (maybe) give for granted: "student-teacher interaction as the place where thinking could be best promoted". As authors like Raths et al. [42] and Sternberg [43] were pointing out, however, the educational programs at the time were more hindering critical thinking than actually promoting it [44]. This early critique was followed by several initiatives to promote thinking, especially critical thinking, in education. It is in the 90's, though that we can see a flourishing of methods in this direction (see Jarvela, 1995; McGuinness, 1993; Perkins and Grotzer, 1997 as cited in [44], dedicated to making students' thinking processes more explicit and, as such, enabling moments of clarification and reflection [44]. Seminal in this regard were the pedagogical experiences initiated by Matthew Lipman in the 70s, and popularized in the 90's, under the name of Philosophy for Children [24]. In this approach, Lipman developed materials and a format aimed at stimulating children's skills and attitudes related to critical thinking and to the ability to hold and dialogue with peers about a shared theme or problem [38]. For instance, [38] invited primary school children to explore the relationship between math and animals. By discussing these, children engaged in discussions about intelligence and values, with contrasting opinions about the higher stand of human beings. Lipman's goal was to 'improve children's reasoning abilities and judgement by having them thinking about thinking as they discuss concepts of importance to them' from a very young age (6 years and above) (Lipman, 1981, as cited in [45]). The activities usually consisted of three steps: 1) reading a novel that includes ambiguities and paradoxes; 2) collecting children's questions regarding the ambiguities and paradoxes; 3) holding a dialogue in the community of inquiry [38]. Together with looking at the teacher as somebody uniquely equipped for stimulating students through open-ended questions and for creating a supportive emotional climate [45], the concept of community of inquiry and the dialogue are of crucial importance in Lipman's approach. In fact, as [38] explain, in the community of inquiry 'all members aim at common objectives, share ideas and information with each other, and try to be impartial and objective in their mutual criticism". By doing so, children internalize concepts and principles of social life (Vygostky, 1985 as cited in [38]). The dialogue, then, is seen as an active and critical method of communication that differs substantially from a general conversation in the fact that it requires complex and social skills. In order to build upon each other's position, in fact, children need: constant attention, meaningful questioning, appropriate argumentations, and constructive criticisms [38].

While this approach has become widely popular over the years, being implemented in around 50 countries across the world [38], experiences bridging it to educational technologies are still missing. Yet, we believe that interesting opportunities for fostering critical thinking could emerge by looking at educational technologies as potentially ambiguous and paradoxical things which could be used as springboards for debate (as the novels in Lipman's approach [45]). In particular, we believe that the controversial nature of robots and their deceptive power, could be uniquely suited for fostering meaningful debate about what this type of artefacts, that we will more and more coexist with in the near future, can do and how they relate to us. Thus, we engaged in a design exploration of robots for fostering critical thinking at school, which resulted in the experience "*Bringing Shybo Home*".

III. Materials and Methods

Reflecting on current approaches to educational robotics and their relationship with children thinking, we conducted a design exploration of what might be the implications of *looking at educational robots as springboards for critical debate*. Specifically, we explored the question of: *how can a robot foster critical thinking and, specifically, reflections on what technologies like robots can do and how they relate to us?* Relating to Lipman's work on Philosophy for Children [24], we developed a playful learning experience focused on stimulating debate among children for fostering critical thinking, rather than building specific technical knowledge. Thanks to a collaboration with *10100 Percorsi*, a private organization that organize educational experiences for schools in Italy, and the primary school *Cesare Battisti*, in Turin, Italy, we contextualized our experience by connecting it to topics addressed in various disciplines of the curricula, such as history, practical life and sustainability. Yet, we structured the activity around the 'pretense' that a robot was found and needed to be brought back home, which allowed us to shift the focus from learning contents to developing a process of inquiry. In fact, a robot was used as an initial narrative component of the activity, in place of the novels of Lipman's approach, and introduced to children by the researchers and an educator from 10100 Percorsi, as 'something' that was lost on the edge of the school garden. The story provided the motivation for children to analyze and debate about the robot and its abilities.

Participants. The experience involved a fourth-grade class of a primary school, composed by twenty 8- to 9-year-old children (M=10, F=10). The class was selected through an existing collaboration between *10100 Percorsi* and the school. Parents were asked to sign a consent and release form, for participation, recording of the experience, and use of the videos for research purposes. The activity was approved by the primary school board.

A. *Bringing Shybo home: a playful learning experience*

The experience consisted of three workshops that engaged a fourth-grade class for three mornings, about 3 hours each. Relevant to the scope of this investigation is only the *first workshop* in which children were engaged in the discovery and analysis of the robot. During this experience, an educator from 10100 Percorsi, accompanied by the main researcher and a creative technologist (involved for technical support), introduced the robot to children through a pretense with the support of a teacher. As we aimed at providing children with a motivation for inquiry, the robot was presented with ambiguity

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Fig. 1. Three phases of the experience: a) Introduction of the robot and preparation; b) Analysis of the robot; c) Making hypothesis about robot past

and a clear call for action. Here a transcript of the educator's initial speech: *"I found this little thing, yesterday in the late afternoon, close to the school garden. I started to look and it reminded me of a robot, but I am not sure because it appears inanimate. None of my attempts to get a reaction were successful. It did not show any kind of reaction. Maybe it's just a broken toy. But as I would like to know more about it, I asked for the help of two robot experts. They arranged a meeting at the school today, because I found this thing close to here. And since the meeting is taking place at the school, I thought that you could also help analyzing it, and see if we can come to understand what it is and where it came from… so maybe we can bring it back home."*

The experience (see figure 1 for an overview) was structured as follow:

a) Introduction. The educator sets up the scene for exploration and inquiry. The researcher distributes the analysis forms. In turns, children read parts of the form, teacher and educator clarify terms.

b) Analysis. Children perform a series of tests on the robot, supported by the form and supplementary materials. They discuss what happens and why.

c) Making a hypothesis. Based on the discussion about the soundtracks, children discuss and speculate about where the robot could come from and why.

Step B was the one in which children were constantly invited to discuss their perception and interpretation about the robot. They discussed and questioned each other's opinion about if Shybo was a robot, how it worked, what it could and not do, and how/why it ended up close to the school. The analysis and discussion were supported by a 'robot analysis form', specifically designed for this experience, and by a teacher who helped the educator and the researcher in fostering children discussion. Given the intent of understanding how using a robot for supporting critical thinking would fit in an existing educational environment, we did not instruct the teacher to act in a predefined way. Before the workshop, we discussed with her the objectives of our investigation and the plan for the activity. Thus, we choose to leverage and learn from the tacit teacher's knowledge and observe how this would help, or not, the emergence of critical thinking. Together with the educator and the researcher, she guided the experience, specifically she moderated the discussions by choosing which child to let speak after raising the hand, posing open ended questions and recapitulating hypotheses and arguments made by children.

B. Materials

Shybo. The robot employed in this study is *Shybo V.2* (figure 1, B). This consists of an extension of *Shybo* [46], which is able to perceive sounds and react by lighting up in different colors and through a minimal non-verbal behavior, namely the movement of the hat. Shybo can be used as part of learning experiences to be carried out in class with groups. The robot does not come with a full range of pre-set associations of colors and sounds, elements determining the behaviors. Rather, it can be trained by children to do those associations and, in doing so, children are invited to reflect on how and why they themselves make those associations in a certain way [47]. The second version of the robot shares the same abilities of the first, but it is also able to perceive colors and react by emitting sounds. As part of the pretense in this experience, the audio tracks corresponded to memories of places that the robot visited before arriving in front of the school. Thus, the soundtracks were previously selected and uploaded, then associated to colors before the activity with children. Furthermore, for the scope of the experience at the school, the robot was programmed to move briefly at irregular intervals of time, with a minimum distance of 15 minutes. This choice of implementing what could be perceived as an unpredictable behavior was motivated by the interest in observing how children would interpret such phenomena that could be described as deceptive. In fact, as [48] demonstrated, an unexpected change in robot behaviors gives rise to an impression in the human of being deceived by the robot.

Analysis form and supplementary materials. In order to facilitate children's exploration of the robot we developed a robot analysis form. This guiding document, figure 1, A, was composed by four main sections: test of voice recognition, analytical observation, analysis of small components, test of color recognition. In each section were listed a series of simple actions and questions for guiding children in the analysis. These were discussed before the analysis and aimed at triggering the formulation of questions and hypotheses in children. Referring to Lipman approach, where ambiguity and paradoxes are used to trigger critical thinking through children questioning, we developed the forms combining objective with perceptual aspects of the robot. By doing so, we introduced an element of ambiguity as perceptual aspects cannot be univocally interpreted and judged. The questions related to the perceptual aspects were

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explicitly inspired by the Godspeed questionnaire series [49] and the taxonomy of socially interactive robots by [29].

We used the lens of social robotics and its characterizing criteria for evaluation, such as anthropomorphism and animacy, to trigger reflections and discussions about the controversial nature of robotic artefacts. In particular, we were interested in observing if children would encounter deception and how they would discuss 'deceptive' factors. As developing critical thinking skills is fundamental for discerning what should be believed to be true and to consciously decide how one should behave in response, our intervention aspire to stimulate children to question what Shybo is, what it can do and how that can be somewhat relevant in their life. Some parts of the analysis guided by the form (table 1), were also supported by supplementary materials: a yellow magnifying glass, a set of colored paper cards, white papers, colored pencils and markers. The most important of these is the magnifying glass. This, introduced with the pretense of analyzing the small components of the robot, was used to trigger the first sound memory. When a child was approaching the robot with the magnifying glass, painted in yellow, unintentionally activated a soundtrack corresponding to a memory. Through this escamotage, children were able to discover the 'ability' of the robot to store memories in the form of sounds and to associate them with specific colors.

TABLE I. ANALYSIS TASKS, RELATED QUESTIONS AND MATERIALS.

Type of analysis	Questions	Materials
Test of voice recognition	Does it understand what it is told? How does it react?	No material
Analytical observation	Does it look friendly or unfriendly? Does it look dangerous or harmless? What does it look like?	No material
Analysis of small components	Does it have hidden components? If so, what can they be for?	Magnifying glass
Test of color recognition	Does it seem to respond to stimuli? Does it seem more static or interactive? Does it seem more natural or artificial? Does it look more like a machine or a living being? Does it seem smart or silly?	Color cards

C. *Data collection and analysis*

The activity was video recorded for subsequent analysis. The video, with a total length of 1 hour and 45 minutes, was segmented into four sections according to the phases of the experience. The first segment, *introduction of the robot*, and the last, *making hypotheses about robot past*, were excluded from the analysis because they did not specifically focus on promoting critical dialogue, rather on setting the stage and closing. We performed exploratory sequential data analysis [50] to observe and understand the behavioral data of children's experience and transcribed the conversations for complementing observations with details from verbal exchange. Videos were coded manually by using *Boris* [51], an open-source software for behavioral observation and coding. Data were coded following the protocol in table 2, developed combining key aspects of experiences for fostering critical thinking with observable behaviors. After a first screening of the video recording, in fact, we identified a series of behaviors relevant for assessing if and how the experience with the robot was meeting the key characteristics expressed in the Philosophy for Children approach for promoting critical thinking: children showing interest and motivation, and the class behaving as a community of inquiry [38].

We focused our observation on *kinetic expressiveness* and *vocal expressiveness* (table 2). As children were observed in the group, we coded both behaviors each through three keys associated with the number of children expressing that behavior: low (1); medium (between 2 and 4); high (5 or more). Regarding kinetic expressiveness we decided to focus on the act of raising a hand as a key indication of interest and motivation of children during the activities. Other kinetic expressive behaviors, such as smiling, laughing and bodily movements that could be considered as indicators of a positive and supportive environment, also a desirable property of educational experiences for critical thinking [45] were excluded from the analysis because of the impossibility of properly observing the behavior of each single child during the group activity. Through *vocal expressiveness*, specifically the intensity of verbal exchange, instead, we assessed the experience success in involving children as a community of inquiry. To properly evaluate this last aspect, the observation of vocal expressiveness was complemented with a qualitative analysis of the verbal exchange. As 'the goal of teaching critical thinking is to stimulate doubts, questions and self-correction in youngsters to improve the personal and social experience (Dewey, 1983; Vygotsky, 1985; Paul, 1990, 1992; as cited in [38]) we transcribed the conversation from the whole experience and manually labeled the segments where we could identify *disagreement* and *argumentation*, or *negotiation and shared understanding*. These indicators were then used to complement the behavioral observation to identify relevant episodes of verbal exchange, which were further analyzed to understand factors triggering dialogue and to generate insights.

IV. Results

A. *Behavioral analysis*

Based on the exploratory sequential analysis of behaviors, we noticed how the activities, where the robot was introduced and children analyzed it and speculated about its abilities, were highly engaging and motivating for the students, and initiated debate. Children willingness to intervene and give their opinion is here identified by the act of raising one's hand, and engage in verbal exchange, which occurred almost constantly. One or more children raised their hand and engaged verbally for almost half of time of the duration of the activities. The remaining time of the experience when no verbal exchange among children was observed, corresponds to adults (i.e., the teacher, educator and researcher) speaking and children testing the robot's abilities. We identified only a single event in which a child did not engage with verbal exchange even when invited to by the teacher (19'.24"). Yet, also in his case we noticed willingness to engage and motivation in a later stage of the experience (29'.42").

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TABLE II. CODING PROTOCOL USED TO PERFORM THE BEHAVIORAL OBSERVATION OF CHILDREN'S EXPERIENCE.

Experience descriptors	**Conditions**	**Observed behaviors**	**N of children**	**Code**
Interest and motivation [38]	Volunteering kinetic expressiveness	Raising hand	1	RH - low
			2-4	RH - medium
			5+	RH - high
Community of inquiry [38]	Vocal expressiveness	Verbal exchange	1	VE - low
			2-4	VE - medium
			5+	VE - high

Despite children's high degree of engagement in verbal exchange (VE), we noticed instances that are at odds with the notion of developing a 'community of inquiry' characterized by a free exchange of ideas. These instances relate to the teacher who had a rather dominant role during the activities, especially with regards to the verbal exchange among students. The norm for verbal interaction in the class corresponds to a sequence of: *raising a hand, being named by the teacher and then speaking*. To a large extent, this familiar sequence was maintained during the activities, and, in the data, corresponds with the peaks in hand-raising behavior followed by verbal exchange. For instance, when children discovered the robot's ability to 'express' itself through sounds (23'.57"), we noticed an increase in children's desire to talk and to perform the tests on the robot, as indicated by the clear correspondence between hand-raising and verbal exchange in the data. At first sight, this rigid class norm seemed to hinder children's genuine exchange of ideas and collaborative interpretations of the situation. Upon a closer look at the data, we could also find peaks in verbal exchange that do not correspond to the act of raising one's hand, but rather happened in a spontaneous way, and thus, broke the class norm. Examples of spontaneous verbal exchange can be found throughout the activities. In some cases, multiple children answered simultaneously to a question posed by the teacher, and thus did not wait for their turn. Other cases are indicative for a clearer *break of the talking norm*. For instance, when children discovered that the robot could react to loud sounds (15'.59") and suddenly moved (42'.45"; 45'.46"), they spontaneously started to comment on what they had observed and made hypotheses by building on each other's reasoning.

B. Discourse analysis

Through the transcripts of the conversations, we further noticed how children were making hypotheses, expressing divergent opinions and/or building on each other reasoning in various moments of the experience. Looking at some specific features of the robot, for instance, children started suggesting possible ways the robot could work. At the beginning (00.25") a child said she saw a red button on the bottom (which is a speaker) and many others said they had seen the same. While reading the analysis form (05'.29") before the actual analysis and discussing what components are, the same child again mentioned she saw a hidden component, the red button at the bottom, and other children followed saying again "I saw it too". When the robot was brought back to the room (13'.42"), after a technical issue, a different child got back again at the same element suggesting that the robot "may work with the red button at the bottom". Similarly, a child also proposed to try and see if the robot works by pushing the mouth (14'.39"). This hypothesis was taken up again later, after the discovery that the robot reacts to loud sounds (17'.36"), by another child who said "*in my opinion, by pushing the mouth the robot can hear better*".

We noticed a similar way of building on each other's suggestions also when children were discussing the appearance of the robot and why it was reacting to sounds in a certain way. Regarding the appearance, children showed divergent opinions about what Shybo reminds to them, varying from Pinocchio, a toy car, a snow man or a mushroom, while others tried to combine these different views, as one girl who pointed out that the robot actually looked like the head of Pinocchio mounted on a toy car. A final agreement regarding the resemblance of Pinocchio can also be noticed at the end of the experience when, all children together, decided to give a name to the robot and the majority voted for Pinocchio. Differently, regarding the why the robot was reacting to sounds with a certain behavior, that is the shaking movement of the hat, children showed an overall agreement with the idea that it must have been scared by something. Despite such general agreement, they had divergent ideas of why the robot was scared. A boy suggested that it might be because they were hurting its ears, while another boy suggested that maybe it is a bit shy. Other children reinforced the second option by also suggesting some nuances, such as the fact that it might be scared because it didn't know them yet. Similarly, when discovering that the robot reacts to certain colors with sounds, children started making hypotheses and building on each other's ideas, such as a student's suggestion (26'.48") that "*colors remember it where it has been, like a place where there was a bit of purple and there were a lot of applauses*" that connects to a girl's opinion (37'.38") that "*it can recognize only the colors that reminds it of something*".

While most of the process of making hypotheses and building on each other's suggestions were focused on understanding very practical aspects of the robot functioning, in some moments we noticed how children tried to explain robot behaviors through the lens of personal experience or the robot nature by using analogies. For instance, at the beginning when discussing the analysis forms and, specifically, what a stimulus is (06'.40"), a child suggested that a stimulus is "*a temptation*" while another explained that checking if the robot reacts to stimuli is like trying out "*to see how it would react when somebody makes fun of it*". Another example is the large use of analogies to discuss if the robot seemed more like a machine or a living being (from 42'.33"). In this case, the discussion started with a child saying that the robot seems both a machine and a living being, but he could not explain why.

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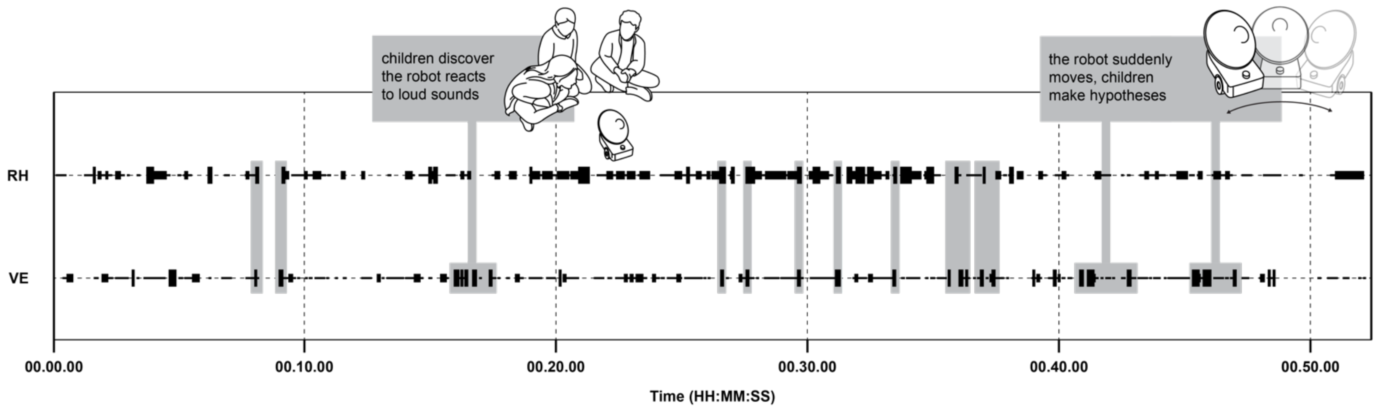

Fig. 2. Occurrence of raising hand (RH) and verbal exchange (VE) behaviors coded and plotted for our exploratory sequential data analysis of the experience

Other children tried to articulate this dual nature by suggesting that since it has some abilities like us, e.g., it can recognize colors, it moves and has emotions (because it can get scared), it must be somewhat alive. Diverging from these main arguments, a child made the hypothesis that the robot "*looks like a mushroom and the mushroom is natural, so the robot might be artificial with a natural shape*". Similarly, another child got back to the topic of emotions stating that "*it is not a live being because it does not have a heart, but it can perceive emotions without a heart*". This remark is again very interesting and connects to the previous as it suggests a richer reflection on the robot abilities and on the possibility for artificial things having abilities analogous to humans yet different in their working mechanisms. In both cases, discussion about stimuli and about aliveness, we noticed how ambiguity triggered more varied interpretations and reflections. Here the discussion moved from mere explanation of what the functioning and vicissitudes of the robot might have been, to broader reflections on the relation and differences with human abilities.

V. Discussion

Looking back at our initial questions of *how can a robot foster critical thinking, and more specifically, reflections on what technologies like robots can do and how they relate to us?* we argue that our study represents a positive example of how this can happen. As discussed in the results, interest and motivation occurred constantly together with verbal exchange, key element for achieving a community of inquiry. As we learned from the Philosophy for Children [24] approach, in fact, these are necessary conditions for promoting critical thinking in learning environments [38]. We can further claim that the study showed the characteristics of a proper community of inquiry as children engaged in a dialogue where they exchanged divergent opinions and built on each other's ideas. In contrast to these positive results, we were also confronted with rigid structuring of interactions that characterize traditional class dynamics, which is a key aspect to address when working with children in educational contexts [52; 53]. The flow of the discussion was fragmented by what we call the *talking norm*, that is a sequence of raising a hand, being named by the teacher and then speaking. This rigid structure (a phenomenon well known in conversation analysis [54]), we believe, hinders a genuine and spontaneous flow of ideas and maintains the leading role of the teacher, while the intention of experiences like Philosophy for children is to make children protagonists of the activity and follow their interests [38]. Nevertheless, we see two positive aspects in not changing the role of the teacher. First, the moderating role of the teacher is fundamental for keeping order and clarity over the activity which would easily end up in fuzzy and not very meaningful verbal interactions. Second, with this approach we could leverage the tacit knowledge of the teacher about class dynamics and personality traits of the single children. This allowed us to avoid having the same students dominating the discussion and ensured that all children felt comfortable expressing their ideas, also those who usually do not easily engage in group activities. Furthermore, noticing *breaks in the talking norm* allowed us to identify pointers of the activity particularly salient for our scope.

Regarding the second part of the question – if *a robot can promote reflections on what technologies like robots can do and how they relate to us* – we are able to confirm our hypothesis that the ambiguous nature of the robot's appearance and behaviors can facilitate discussions about how the robot functions, its perceived intelligence and intentionality, and how its abilities relate to abilities of humans and other living things. In particular, we noticed the emergence of these reflections in correspondence of two types of situations: when children were explicitly asked to express their opinion about the robot in relation to aspects of animacy and anthropomorphism; and when the robot was unveiling some unexpected behaviors, such as reacting to sound through the movement of the hat, recognizing colors and emitting sounds, and briefly moving into space. In both cases, we (the adults) induced children to think, or consider the possibility, that the robot had certain abilities, such as the capacity of understanding its environment. Specifically, this happened through the use of the analysis form, that explicitly asked children questions like "*is it more like a machine or a living being*?", and through the robot behaviors that, because of their reminder to familiar behaviors or their unpredictability, were anthropomorphized. As a matter of fact, the movement of the hat was explicitly designed to remind of scared creature that hides and shakes, while the apparently random movement in space was designed to foster a sense of intentionality.

These choices represented an explicit act of deception we performed through the robot. We aimed at letting children reflect on the dual way we (and especially children) tend to perceive robots, both animate and inanimate, or better as a new

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ontological entity that sits in between the two [55; 56]. A traditional definition of deception, in fact, describes it as the act of intentionally causing a false belief that is known or believed to be false [57]. In the specific case of robots, this process is said to be occurring when the appearance and/or the way a robot is programmed to behave, creates the illusion of sentience, emotional capabilities, ability to care or understands humans [3]. In our experience, we were aware of the limited abilities of Shybo, yet we intentionally presented it as a social robot and suggested that it could have higher abilities than the one it actually had. This decision was based, on the one hand, on the aim of using the robot as springboard for debate, inspired by the work by [24] in which it is important to introduce elements of ambiguity and, on the other hand, on the aim of connecting with the broader reason why we claim there is need for critical thinking in the first place, that is being able to critically deal with technology and its (false) promises. Nevertheless, using deception as a strategy in our project may seem counterintuitive. *Why should we deceive when we are arguing that children need critical thinking skills for dealing with technology-related deception?* The answer lies in the open debate that characterizes the topic of deception within the field of HRI studies. As [3] discuss, several authors are providing different, often contrasting, perspectives on the topic and there is a need for richer discussions of what constitutes deception in social robotics and when it is wrong. Despite the different perspectives, in fact, there is general agreement that deception can be a beneficial strategy to achieve positive and successful HRI [3; 58; 59; 60; 61; 62; 63] as it happens already for humans [3; 64] and animals [3; 59; 61]. According to some [59], deception is even seen as a necessary condition to build intelligent and interactive robots, a fundamental feature for achieving high-order intentionality. While engaging with this particular claim is out of our scope, our project relates to the broader underlying idea that deception, under certain conditions, could be beneficial for the deceived, thus, an acceptable strategy in HRI. This idea, usually addressed under the name of *other-oriented deception* [59] or *benevolent deception* [65], may be valid in stressful or life-threatening situations [59], or in situation where the aim is to promote suspension of disbelief for fun and enjoyment [3; 59], as it happens with movies or magic, where the deceived voluntarily allows herself/himself to be deceived [59].

In our study, we engaged with the idea of benevolent deception hypothesizing that the deceptive potential of a robot could be exactly the aspect that would make robot uniquely (or at least distinctively) suited for promoting children's critical thinking at school. Accordingly, we used deception to promote suspension of disbelief and to bring children ‘inside’ a story. Most importantly, the ambiguity of robot behaviors was used to spark interest and trigger reflections. By discussing the robot abilities, then, children demonstrated a critical mindset towards this technological artefact and, to some extent, a capacity to go beyond its deceptive power. First reactions of children were usually focused on attributing the robot abilities much higher than what it was capable of, such as intentionality and memory, coherent with the intentions of the research. Through discussion, however, these first impressions were usually elaborated and revised into more careful considerations of what a robot, in this case Shybo, is and could actually do. For instance, when discussing aliveness, a girl supported the idea that the robot could be somewhat alive mentioning that since the robot got scared when a boy was talking to it, it maybe has feelings. This idea was soon revised through the comment of another child that rejected the hypothesis that Shybo could be somewhat alive, arguing that it does not have a heart, rather, it could have the ability to recognize feelings, without a heart.

Thereafter, this experience represents an example of how robots can be used to promote children's critical thinking and illustrates how this could allow addressing aspects of robot identity and abilities. In doing so, we also implicitly respond to the question by [59]: *can robot deceptive behaviors benefit the deceived human partner in HRI context?* We argue that, in the specific case of educational robots, the answer is yes. Provided, however, that the robot and its deceptive behaviors are explicitly used to trigger children’s reflections and critical thinking about the robot itself, or relatable concepts. We suggest that HRI designers should look at deception, and its possible benevolent role in child-robot interaction, as a form of pretense play. In pretense play, children are aware that they are engaging in a pretense. As [66] explains, if you ask children who are playing with a doll what they are doing, they may tell you that the doll is shopping or is sick, but they would also be able to tell you that they are enacting this scene and that it is not real. Open remains the challenge of making sure children perceive the intended form of robot deception, while being aware that it is an illusion, not a reality [4].

VI. Conclusions

In this explorative study we learned that even a simple and low-anthropomorphic robot can be used to promote critical thinking in educational contexts. Contrary to the belief that robotic deception should be avoided (or at least limited), we suggest that this robot feature can be used purposefully and meaningfully to achieve a benevolent form of deception that scaffolds children's critical thinking, at least when embedded in carefully designed educational activities. Our provocation for HRI designers, then, is to *embrace and magnify robot aspects with deceptive potential, such as personality and intentionality, so that they become explicitly controversial and may be used as a springboard for a critical debate.* This allows children to engage, evaluate and establish a personal understanding of the nature of social robots. Through this provocation, we do not only invite HRI designers to rethink the way we approach the design of social robots but also, and foremost, to reflect on the role we attribute to robots in relation to that of educators, who in this perspective retain a crucial role. Further, this provocation represents a concrete strategy for nurturing children’s critical thinking about emerging technologies, as it incorporates elements of ambiguity that connect to the types of challenges, such as the problem of non-human agency, that children will face when confronted with social robots and other types of artificial social agents in the near future. As such, it opens up opportunities for reflecting on the ethical and moral implications of social robotics in society, through the views of children.

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