Robot Co-design Can Help Us Engage Child Stakeholders in Ethical Reflection

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***Abstract*—Children are stakeholders of robotic technologies who deserve to have their voices heard in the design process just as much as adult stakeholders. This is especially true for robotic technologies explicitly designed for child-robot interaction, in areas like education, healthcare, and therapy. Researchers face the challenge of cultivating children's critical awareness on the design of robots and accompanying ethical concerns, as the types of exercises typically used to engage with adult stakeholders can be ineffective with children. This requires developmentally appropriate methods for understanding children's perspectives that also address the imbalanced power dynamics between children and adults—such that children feel comfortable sharing their ideas. In this work, we demonstrate that participatory design research techniques already accepted in the Human Robot Interaction (HRI) community can fulfill this purpose. Specifically, through the design and analysis of two co-design workshops with children of different ages at a school in Denver, Colorado, we demonstrate that co-design workshops can be used to effectively understand how children make sense of robotic technologies and to facilitate children's critical reflection on the ethical dilemmas surrounding their own relationships with robots.**

***Index Terms*—Child-robot interaction, co-design, participatory design, robot ethics**

Fig. 1. In this paper, we explore how co-design workshops can evoke children's perspectives on robot relationships and the ethical concerns they present—a key requirement for designing technologies whose stakeholders include children.

I. Introduction

A central principle of design frameworks such as *Engineering For Social Justice* [1] is that technology design should be grounded in contextual listening to the communities that will be impacted by technology. Through contextual listening, technologists and stakeholders can mutually explore the ethical dimensions of potential technologies, understand communities' appraisal of the risks involved, and consider how those risks relate to communities' priorities, values, and goals. Moreover, professional codes of ethics such as IEEE's [2] make clear that engineers must communicate techologies' ethical risks to stakeholders and to other researchers.

Human Robot Interaction researchers are creating interactive robotic technologies for children, especially in the contexts of education [3, 4] and healthcare or therapy [5, 6, 7]. While there are clear prosocial reasons for developing technologies to assist children, there are also clear ethical risks to these technologies—especially with respect to the relationships children may form with robots [8, 9, 10]. Child Robot Interaction researchers have a duty to understand how children make sense of robotic technologies and develop positions towards these associated risks, and to incorporate those positions into their design practices, just as they would with any other stakeholders. However, HRI researchers must practically explore the perspectives of children on such matters. Engaging children in this way presents several key challenges. Exercises that resonate with adult stakeholders—such as focus groups or interviews—can be ineffective with children. Children require developmentally appropriate explanations of technologies and the way they are designed, and accessible means to explore and express their own ideas [11, 12, 13, 14]. All of these challenges are exacerbated due to the typically imbalanced power dynamic between children and adults [15, 16, 17]. To understand social robots' role in children's lives, van Straten et al. [8] argue that researchers must investigate children's responses to robots in settings where robots' status as social, mental, or moral others is not rendered by adults, and can instead come from the children [8]. However, the imbalanced power dynamic between children and adults makes it difficult for children to confidently share their ideas without feeling a need to perform for or please adults [15, 18, 19].

Our key insight in this work is that researchers in HRI have already developed methodologies that can address these challenges. Specifically, we argue that *participatory design* research methods such as *co-design workshops* can be used to understand how children make sense of robotic technologies and the ethical dilemmas surrounding child-robot

relationships. This paper combines existing ideas about the value of reflection in co-design with established methods for conducting accessible and egalitarian design activities with children. The core contribution of our work is a demonstration that co-design methods are well-suited to facilitate children's critical reflection on ethically fraught topics in child-robot interaction.

Participatory design is a design research methodology that explicitly involves stakeholders in the design process [20, 21]. It has a deep tradition of translating the ideals of democracy and empowerment into design practices [21]. Participatory design research is well-aligned with key goals of the HRI research community, such as moving research outside the lab and into "the wild" [22, 23, 24], as participatory design research allows technologies to be studied in the actual setting where they exist or may exist in the future.

We argue that co-design in particular is well suited to promote critical reflection with children for two reasons. First, co-design methods are developmentally appropriate and exciting to children. Drawing, making, and role-play are familiar activities that allow children to express complicated ideas without worrying about writing things down or sitting still for too long [13, 25, 26, 27]. In addition, participatory design carries a fundamental tradition of power-sharing with stakeholders—indeed, the history, theoretical grounding, and methodological conventions of children's co-design all emphasize children's empowerment as experts in their own lives and the creation of an equal dynamic between children and adults [19, 21, 26, 28]. For these reasons, co-design both supports children's needs and encourages researchers to value their voices.

To validate this argument, we conducted and qualitatively analyzed a pair of co-design workshops which introduced elementary-age children to established concepts and ethical concerns in child-robot interaction, and encouraged them to engage with those ideas through design exercises. The results of these workshops show that co-design activities can successfully support children in comprehending and exploring these ideas with imagination, creativity, and nuance. Our results show that co-design workshops are an effective way of evoking children's positions and perspectives on those concepts and concerns.

II. Related Work

A. Participatory Design

Within HRI, participatory design efforts have involved a wide range of users, including children [13], teens [29], elders and their caregivers [30, 31], the blind [32], and users of augmented communication devices [33]. Participatory design activities, such as co-design workshops, can be particularly effective when technology stakeholders are children. Participatory design with children has helped build technology focused on literacy [34], creativity [13, 35], and scientific education [36]. However, engaging children in design research is difficult. Researchers must help children understand the scope of technology, organize and express their ideas, and build trust in the power sharing dynamics of the design process [18, 19]. Once these challenges are met, the insights, frustrations, and inspirations that children experience are just as legitimate as those of adult participants [11, 26].

B. Critical Reflection

Reflection involves bringing potentially under-explored aspects of an experience to conscious awareness and making them available for deliberate consideration; in this way, it is integral to how humans see and experience the world [37]. Within the design process, critical reflection includes the exploration of goal-directed problem solving in a way that "steps back" and achieves psychological distance from one's experiences [37]. As a multi-faceted metacognitive skill, reflection is critical for child development. Children must learn to re-combine information in new ways to form a more elaborate understanding of their world [38].

Critical reflection plays an important role in HRI and HCI research with children, especially in participatory design. Co-design can encourage children's "critical and reflective stance" about technology, as defined by Iversen [17]. This stance begins with the new insight and skills that children gain during the design process and expands to include children's nuanced perception of technology, critical thinking about its role in their own lives, and empowerment to make decisions about technology in the future [17].

Researchers must adjust traditional methods to be developmentally appropriate and exciting to children in order to facilitate children's critical reflection [11]. Specifically, researchers must choose methods that overcome researcher-child power dynamics and address children's difficulties with interviews and surveys [39]. Narrative techniques and game-like activities are an excellent way to meet this challenge. They can promote self-reflection [3], help children understand the scope of design problems [40], and encourage discussion about technology ethics issues [39, 41]. Such methods allow children to explore their own values, models, beliefs, and opinions with respect to the role of technology in their lives [39].

C. Critical Reflection in Participatory Design

It is important to note that critical reflection is always present in different parts of the participatory design *process*. Researchers themselves must reflect on their own intentions and methods before involving their design partners. This kind of critical reflection helps researchers evaluate their own assumptions, identify blind spots in their design goals, and open new design spaces [42]. Researchers' critical reflection then provides the basis through which they can develop an appropriate methodology for their participatory design goals [28].

Reflection also facilitates the iterative nature of design and promotes mutual learning between researchers and participants [11]. Asking for participants to reflect helps researchers understand their perspectives more richly and identify new directions and challenges in the design process [43]. Reflection guides researchers to improve their co-design procedures [44, 45], as well as create design activities that emphasize

participants' agency [16]. This reflexive practice promotes the mutual empowerment of all involved [19].

Reflections on technology, ethics, or design can also constitute an *outcome* of participatory design efforts. Reflection is a core contribution of design research because it emphasizes the societal implications of technology [42]. In this way, participatory design research generates social knowledge—rich descriptions of the social environment in which a technology exists or will exist in the future [28]. This sort of research contribution highlights the values held by technology stakeholders [28] and explores larger social practices that will affect the way technology is used [42].

Reflection matters in design research because it is part of a holistic design process. This is especially important when children are co-designers. There are tremendous benefits to including children as contributors in all stages of design, not just as testers of relatively complete designs [26, 36]. Critical reflection is a key part of giving children this more holistic role in participatory design. When children are given agency in the design process, they are empowered to develop Iversen's "critical and reflective stance" towards technology [17]. By positioning reflection as an outcome of design, researchers can encourage children's critical thinking and invite them to take more ownership in the design process [17, 19].

D. Ethical Dilemmas in Child-Robot Interaction

This paper argues that participatory design methods are well-suited to facilitate children's critical reflection on ethically fraught topics in child-robot interaction. Specifically, it is concerned with ideas that center on features of child-robot relationships, such as trust, deception, and emotional bonds.

A wide variety of ethical concerns pertain to the increased presence of social robots in children's lives. A key question in this space is how children will conceptualize of and form relationships with robots. Research suggests that children's mental models for robots overlap with, but do not entirely coincide with, their conceptualization of humans, animals, or inanimate objects [46]. Children tend to imbue the behavior of robots with human-like characteristics, such as feelings and social motivation [47, 48]. In addition, the way robots present themselves or are presented by adults also affects children's perception of them as social, mental, and moral others [49]. In turn, this affects children's acceptance of emotional behavior towards robots [49]. This leads to the unresolved ethical question of what kind of relationships could or should children have with robots. Many facets of this question are currently being explored, including the long-term implications of child-robot relationships [48], the role of trust within them [50], and whether or not it is always beneficial to imbue robots with human-like behavior [8, 50].

Another closely-related ethical topic is the role that deception plays in child-robot interaction. Because children so readily perceive social robots as social agents, researchers are concerned about the extent to which robots deceive children about their capabilities. It is also well-understood that children relate socially to robots, especially when they are presented with backstories that do not accurately reflect the robot's mechanical nature or limited cognition, such as during wizard-of-Oz interactions [8]. These findings raise key ethical concerns. For example, children show willingness to tell robots their secrets [51], which raises further questions about children's privacy and persuadability in such scenarios [8]. Fundamentally, robots that deceptively encourage children's empathy, trust, and acceptance could be problematic [49]. This is especially the case as robots emerge into more integrated or authoritative roles in children's lives—as caregivers, teachers, or companions [49].

These ethical issues are complicated and touch on topics that range from modes of robot operation to human cognition and affect. In this paper, we will show that co-design can help children themselves explore these ideas as serious stakeholders in future robotic technology.

III. Methodology

We conducted two IRB-approved co-design workshops. The objective of our workshops was to address the central question: *Can co-design activities facilitate critical reflection on child-robot relationships and elicit children's positions, perspectives, and sense-making procedures regarding robots and the ethical concerns surrounding their use?*

We narrowed the scope of this central question for the purpose of planning the workshops. Specifically, we focused on ideas about child-robot relationships and the issue of deceptive robots, as described in the related work. This was necessary to provide a springboard for discussion while avoiding too broad of a discussion space. These topics are certainty not an exhaustive list of ethical concerns in this space; however, we chose them as a way to set a clear scope at the beginning of the workshop. Children in both workshops quickly expanded upon these springboard ideas. We also narrowed the scope of our workshops to focus specifically on children's perspectives these questions in robot ethics and design, as opposed to how children think about related social issues in general.

A. Workshop Setting and Participants

Our workshops took place at a forest school in Denver, Colorado. The school centers educational practice around the outdoors with a heavy emphasis on social-emotional learning, and aims to create a welcoming environment for neurodiverse and twice-exceptional students. The first workshop was conducted with eight children in grades 2 and 3. The second workshop was conducted with twelve children in grades 4 and 5. Though we did not collect data on participants' age, we will note that the usual age of US children in those grade levels is 7-9 for the younger group and 9-11 for the older group.

These workshops were facilitated by an existing relationship between the researchers and the school through an education outreach partnership. Accordingly, workshop participants were already familiar with some robotics concepts and had met researchers before, which helped facilitate trust. Researchers enjoyed the challenge of creating a workshop plan that could take place entirely outside.

B. Workshop structure and execution

The duration of each workshop was about 3 hours. Both workshops had the following structure: (1) consent and assent; (2) initial discussions; (3) constructive design exercises (sketching and prototyping); (4) video interviews to encourage continued reflection; (5) interaction design using a robot teleoperation tool; (6) workshop debriefing. This paradigm allowed us to interrogate children's perspectives through multiple modalities.

*1) **Consent and Assent**:* We began by collecting parental consent and child assent. Parents were asked to opt-in to each form of data collection used in the workshop, including photos, videos, and anonymous quotes. We emphasized to parents that their decisions would not affect their child's experience and that no student would be made to feel left out of an activity for any reason. Children similarly signed assent forms, and then participated in a discussion that provided further explanation about the research process, in accordance with [16].

*2) **Initial Discussion**:* Our workshops began with introductions around a picnic table. Researchers explained our goal of writing a research paper, which is a report that other researchers would read. We explained that participants' ideas would be anonymized and that anyone could decline to have their ideas in our paper without missing out on any activities. This explanation was the only scripted portion of these introductory discussions. This script was inspired by Read's guidelines [16]. The purpose of this script was to create ethical symmetry with children by helping them form an accurate understanding of our work and of what would happen to their ideas. It was not explicitly related to our goals surrounding critical reflection, and was instead about researchers providing transparency about the workshop, which is an important part of power sharing in any participatory design process. The explanation scrip itself is available in our OSF repository, at tinyurl.com/MottHRI2022.

Following these introductions, researchers led an informal discussion exploring the ideas children already had about design. During these conversations, we showed a physical example of a foam robot prototype borrowed from Fine Art Miracles, Inc. (a collaborating social robotics nonprofit), and talked about the differences between it and a photo of the final version of that same robot.

Next, we introduced ethics-related topics in Child Robot Interaction through our springboard ideas. These topics were introduced through storytelling, which is a developmentally appropriate way explore abstract ideas with children [18, 41]. Researchers read a series of short, 6-10 sentence stories adapted from relevant research papers or from the experiences of our collaborators. The goal of these design stories was twofold. First, they presented our springboard ideas in a narrative way. Second, they aimed to empower children to engage with the flexible nature of design. For example, we intentionally chose stories that involved robotics researchers exploring ambiguous issues, changing their minds, or asking questions about human emotions. In this way, we wanted children to feel inspired to consider ambiguous concepts themselves and to feel comfortable changing their minds about those concepts during the workshop. In addition, two of our design research stories focused on preschool-age children, several years younger than our workshop participants. We did this as a way to introduce a user population relative to whom our participants could feel more experienced, and about whom our participants could feel competent speculating.

Here is an example of one story used in our workshop, adapted from Melson et al. [46] work on preschoolers' impressions of Sony's AIBO:

Some robotics researchers were curious about how kids think about robot pets. They decided to compare how preschoolers play with a robot dog named AIBO and a real live dog. They asked the preschoolers questions: Is this dog alive? Can it feel happy? Does it understand you? Can it really be your friend? Is it okay to kick it?

Most of the preschoolers agreed that AIBO the robot dog wasn't really alive, but many of them thought it could still feel happy or feel left out. Some of the kids also thought that they would feel comfortable telling secrets to AIBO. Some thought that it would be wrong to ignore AIBO if it sounded hurt —just like a real dog.

The researchers decided that it was interesting how little kids think of a robot pet as something that is in between an inanimate toy and a real animal. However, they were also concerned because a lot of the little kids they talked to seemed to overestimate AIBO, which is still a programmed robot that doesn't have feelings and certainly doesn't really feel pain. They wondered about questions like: what happens if a little kid tells a robot something personal because they don't realize that it isn't like a real animal?

After each design story, we facilitated a few minutes of free-form conversation about the choices, dilemmas, and questions involved. For example, after the AIBO story, we asked participants to speculate about whether their little siblings or cousins would assume a robot pet had real feelings, and to consider how they would feel if someone in their life told secrets to a robot pet because they misunderstood its abilities. In this way, aimed to encourage participants' critical and reflective stance [17] about robot relationships. We invited discussion and disagreement after each design story and primed children to think about how they would address each topic in their own decisions and designs.

*3) **Constructive Design Exercises**:* After the design research stories and discussions, children engaged in sketching and prototyping. We asked them to imagine a robot that would interact with children like them in the future, that was inspired by something they thought about during the design stories and discussions.

First, children sketched their ideas of how a robot might look (Fig. 2.1-2). The worksheets also included optional guiding questions. Children completed their design drawings outside at (or around) an outdoor picnic table.

Next, we invited children to prototype their robots (Fig. 2.3) using materials from their school's supply room such as

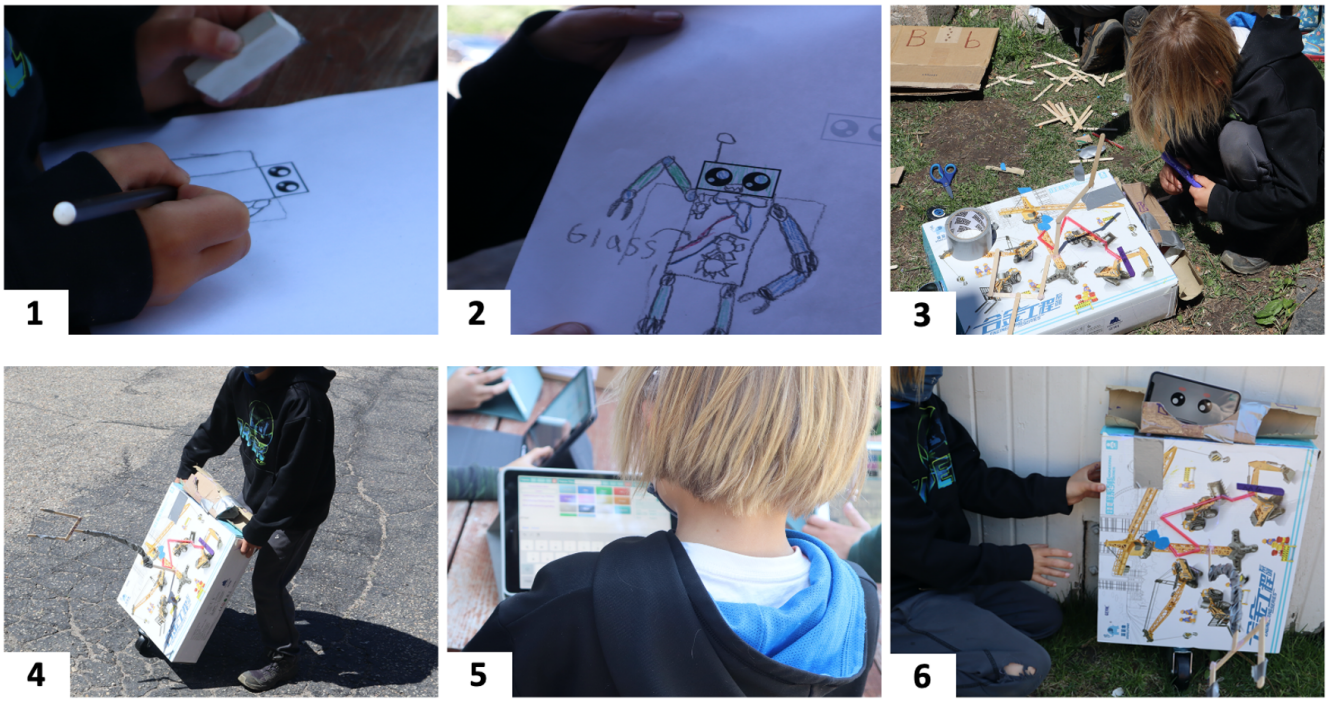

Fig. 2. The workshop design process for this "glass-tummy" robot involved design drawing, prototyping (note how the toy box evokes the glass-tummy effect), a parking lot test drive, creating conversation buttons, and testing an interaction.

cardboard, cloth, and castors. Participants built prototypes at the picnic table, on the grass, or underneath trees. A few took their mobile prototypes for parking lot test drives (Fig. 2.4).

*4) **Video Interviews**:* During prototyping, we conducted a video interview activity with small groups of 2-3 children underneath a large evergreen tree (or in it, as the tree was good for climbing). Children alternated being the camera-person and being an interviewee. In this way, participants recorded each other, instead of having an adult researcher control the camera. This choice was made in order to help participants feel that they were not performing for or being tested by researchers. During the activity, a researcher seated on the ground introduced questions about about hypothetical child robot interaction scenarios. These questions were also inspired by our springboard ideas. Examples include:

- Suppose your class takes their robot on a nature walk, do you imagine the robot already knows about nature, or do you and your classmates teach the robot about the things you find?
- Do you think a classroom robot should be in charge, like a teacher? How would that make you feel?

The full list of questions, along with other workshop materials, is available in our OSF project, at tinyurl.com/MottHRI2022.

*5) **Interaction Design**:* Because our motivation for conducting these workshops was centered on child-robot relationships, we wanted participants to explore interaction design, as well as morphological design. Our goal was for children to understand that robot design means making choices about how a robot speaks, acts, and interacts, as well as how it looks and moves. To this end, we included an interaction design activity, in which children could prototype conversations with their robot. This activity provided a bridge between children's physical prototypes and the design story discussions about child-robot relationships. Furthermore, it gave children an opportunity to make decisions about the kind of robot behaviors and human-robot relationships they would prefer.

Once participants completed their prototypes, they used the Peerbots app, an open-source teleoperation platform developed by collaborators at Peerbots Inc., to design interactions for their robots. We demonstrated how participants could create interactions and conversations using the app's controller on an iPad, and then place a phone into their robot prototype's face and have their robot talk and interact the way they designed. Students sat together at the picnic table or gathered in shady patches of the yard to design their interaction buttons (Fig. 2.5-6), and researchers helped them test their interaction designs in small groups.

*6) **Workshop Debrief**:* At the end of the workshop, we gathered participants for another informal discussion. Researchers asked them what their favorite part of the day was and reiterated our workshop goals. We asked children to share about when they had changed their minds about their designs and what ideas stuck out to them, and revisited ethical scenarios about robot relationships, deception, and affect.

C. Power Sharing Strategies

We implemented several power-sharing strategies to encourage children to feel that their ideas were being taken seriously by adults. Before the workshops, we used Read's CHECk guidelines to reflect on our motivations and values and to consider our treatment of children's intellectual property [16]. We also shared iterations of our plans with teachers and school leadership and gave them opportunities to provide feedback.

During each workshop, we emphasized to children that we (researchers) were here to learn from them. This emphasis was created through the design of our activities, such as our scripted explanation of the research process in the initial discussion and our choice to have children record one another during video interviews.

We also used the following additional strategies: dressing informally and in bright colors, not enforcing hand-raising, sitting on the same level as kids (researchers got a lot muddier than expected), choosing familiar childhood spaces, using familiar materials, having participants record each other instead of performing for adults, and striving to genuinely listen and treat discussions like real conversations.

IV. Workshop Analysis

A. Data Collection

We collected a variety of data from each workshop. These data included notes, photographs, drawings and physical prototypes, videos from the interview activity, and the conversation buttons children created during the interaction design activity. Researchers collected data collaboratively—for instance, one researcher took notes while the other led the design discussion. After the workshop, children's quotes, designs, and interaction buttons were reconciled to the best of researchers abilities so that they appear together, yet with anonymized names.

B. Data Analysis

We performed a grounded theory analysis [52] of the various forms of data collected during the workshop. First, we performed an *open coding* process in which all forms of gathered data were tagged for their characteristics. Then, we performed multiple iterations of an *axial coding* process, in which these initial observations were organized and synthesized. In this section, we share results of this analysis. All participant names below have been changed.

V. Workshop Results

Because our goal was to facilitate critical reflection, our analysis was centered on children's thought processes and sense-making procedures, not their actual designs. The design process was an accessible, creative way to support children's conversation and encourage exploratory thinking. Additionally, we do not claim that the content of our participants' designs is generalizable. We discuss this choice more in section VI-D.

Fig. 3. Workshop participants sat outside together and designed interactions buttons to test on their robot body prototypes.

A. Children's Understanding of Design

Our workshop depended on the success of our "demystifying process" [11], such that children could make connections between the ideas presented in our design story discussion and their robot design process. Exploring these connections allowed them to think critically about robot relationships and to make decisions about their own robot design, both components of a critical and reflective stance [17].

Children in both workshops easily imagined activities that would take place in the design of a social robot, and indicated an understanding of how design is flexible and iterative. Noah, a second grader, attested that the design process includes *"how you think the robot is going to work."* Fifth grader Diego mentioned that *"Design means making something actually helpful."* Children also made connections between how a robot is designed and how users would expect it to behave. Avery supposed that a friendly robot should *"have a soft, gentle voice."* Claire agreed that *"a friendly robot should have a calming voice, so it doesn't give you a headache.'*

Participants were comfortable with the idea that robots only did what they were programmed to do, no matter how intelligent or affective they seemed. This is perhaps unsurprising as they were already engaged in a robotics curriculum. When asked in a video interview about the intelligence of future robots for children, Jacob countered *"Well, it depends on his program."* During our design story discussion about robot-dog AIBO, Noah joked that programming a robotic pet would mean that *"at least you don't have to train it."*

Despite this understanding of robots' programming, participants showed mixed mental models of robots' intelligence and capabilities. During our design story discussion about AIBO, some participants understood that *"AIBO has no emotion"* and that *"AIBO isn't alive—that's what creeps me out."* But another participant thought *"AIBO is a lot smarter than me."*

Overall, children readily imagined how the ideas and ethical dilemmas presented in our workshops connected to the design process. In particular, they intuited connections between a

robot's design, user reactions and expectations, and the corresponding impact on human-robot relationships. In this way, we demonstrated that our co-design methodology successfully created the foundation for children to engage in critical reflection and explore ethical dilemmas.

B. Children's Critical Reflection

Children in our workshops demonstrated nuanced critical thinking and reflection about robot relationships and the ethical challenges they pose. For example, one major category of discussion in the workshop was the role of authority in child-robot relationships. In general, children valued authority and expected to be in charge of both hypothetical future robots and the robots in their designs. They were hesitant about the premise of future robots being in charge of children—such as in teacher-like roles. In our debrief, Madison emphasized that she hoped adult designers of future robots would make sure that children can *"talk to it and give it commands."* Authority was a consistent theme in the interactions children designed for their prototypes on the Peerbots app. Several participants created conversation buttons for robots to refer to them as "master" or referenced other tasks children would instruct the robot to do. During video interview activity, most participants supposed that children should be in control of robots. When asked why, Matthew joked *"Kids don't even listen to teachers sometimes! Why would they listen to a robot?"*

However, participants also thought critically about their preference for authority. Several groups of children independently and voluntarily explored the idea that they might be willing to suspend their authority over a future "classroom robot" in an emergency situation. This scenario was of their own devising and wasn't present in any interview questions nor design stories. Children explained that, despite wanting to be in charge of their robots, they would reconsider this preference under certain circumstances. This is an excellent example of critical thinking and reflection. It shows how children took initiative to extrapolate beyond the original springboard ideas that researchers introduced—they interrogated their own assumptions about authority by speculating about edge-case scenarios. In this way, they brought an under-explored aspect of their experience (emergency situations) to conscious awareness and deliberately considered it [37].

Children also engaged in critical reflection about the role of affect and deception in child-robot relationships. For example, recall that one of our introductory design stories was about research comparing preschooler's mental models of AIBO to their mental models of a living dog [46]. We challenged children to consider the premise of emotional bonds with AIBO by asking them about whether or not they would feel comfortable telling a secret to AIBO, and how they would feel about a younger child doing the same because they mistakenly thought AIBO had real emotions. We chose the secret-telling scenario because it created a more concrete dilemma, as children can struggle to abstractly describe their thoughts about technology [15]. Many participants agreed that a robot's capabilities influence whether or not it is okay to trust a robot with your secrets. Jacob stipulated that *"I would feel comfortable (telling secrets), but I would have to get to know about it first."* Isaac said that *"I might choose a robot dog over a real dog (to tell a secret) because it doesn't really know what I am saying."*

Children in both workshops explored the potential ethical harms in our AIBO story, even when researchers did not explicitly guide them in that direction. Specifically, they understood that the secret-telling scenario created security and privacy issues, in addition to the deception issue that researchers initially introduced. Many participants shared thoughts such as *"What if someone steals the secrets?"* Madison added that *"I'd rather tell a real dog a secret"* because it was more secure. Children made connections between the robot's data gathering and these potential vulnerabilities. Logan emphasized that a robot dog *"can spy on you."* His classmate Noah asked *"What if someone hacks the robot?"* Claire also added that, even without a deliberate hack, *"the robot dog could just malfunction and start talking and say your secret to everyone."*

We asked participants to revisit the same dilemma in the workshop debrief, after they had continued to explore their ideas through the design activities. In the debrief, they made compelling suggestions about how to address the issue of future children mistakenly thinking that robots have real emotions. One participant suggested that future robots should be *"smart, but honest,"* meaning that they should be highly interactive but not actively deceive their users. This idea received lots of agreement. When asked how this might be implemented, Claire suggested *"On the instruction manual (for the robot), it should have questions you can ask the robot like "do you have real feelings?" and then the robot shouldn't lie about it—it should say no."*

Children demonstrated a critical and reflective stance on the role of deception in child-robot relationships. They established this stance in the initial discussion and continued to explore it through design activities. They comprehended additional ethical implications of the topic beyond what researchers introduced and felt empowered to propose constructive solutions to adults. Children also considered how this issue would affect others, including younger children, children in the future, and children who had not learned about robots yet. In this way, they also demonstrated critical reflection by seeking "psychological distance" from their own experiences [37].

These results show that our participatory design methodology successfully facilitated children's critical reflection on ideas and ethical dilemmas related to child-robot relationships. By grounding these concepts in narrative storytelling and familiar, creative activities, we showed that researchers and children can mutually explore the connections among technology, ethics, and design.

VI. Reflections on Our Methods

Our work shows that children can be active participants in investigating and untangling conceptual questions and ethical dilemmas surrounding their relationship with robots. The principles and methodologies of participatory design helped

our participants to confront these ideas as experts in their own lives and engage in reflexive practice as stakeholders of future robotic technology. This suggests that co-design workshops can be used to fulfill designers' duty to consult children as stakeholders in the design of robots that will impact them. In this section, we reflect on the aspects of our approach that presented the greatest successes and the greatest challenges.

A. Co-Design With Different Age Groups

Though we conducted the same workshop with both of our age groups, we noticed differences in how they interacted with our design activities and how we chose to adapt accordingly. The 2nd and 3rd grade workshop group had an understandably shorter attention span for discussion activities, while the 4th and 5th graders were happy to have more prolonged conversations with researchers. Both groups most enjoyed prototyping and building activities. The younger group jumped right into the prototyping process after sketching their designs and were less worried about perfecting their physical prototypes. The older group had more specific visions and expectations for their prototypes, which led to more anxiety about having enough time to finish them. This was especially true when we asked small groups to step away from building for the video interview activity. In response to this stress, we affirmed that the video activity was optional, cut down on the time it took, and tried to hold the same discussions with participants while they were still prototyping. Were we to repeat this workshop, we would likely cut out the video activity entirely. Since prototyping was quite social for both groups of children—some even elected to work in pairs—it would have been natural to have informal discussions in that setting.

B. Reflections on the Scope of Our Workshops

The goal of our workshops was to facilitate critical reflection through design activities, not to complete a full design for a specific piece of robotic technology. A complete co-design process often takes time and iteration to examine assumptions, balance norms of participation, and review ideas [14, 45]. We did not expect this sort of long-term reflection to take place within the scope of our workshops. We chose to do a single co-design session because our workshops took place near the end of a school year in which students, teachers, and school leadership had already faced scheduling challenges on account of the COVID-19 pandemic.

C. Reflections on Power-Sharing Methods

Power-sharing is an integral part of all participatory design. The power-sharing methods we implemented were not specific to our goal of facilitating critical reflection. However, we can note which methods were more resonant with participants. In both workshop groups, children responded more to our action-oriented power-sharing choices, such as not asking for raised hands or controlling how children interacted with the materials we brought. Our introductory descriptions of the research process was less resonant, as it was very abstract and children were very excited to get into the creative parts of the workshop. In the future, we would seek more interactive ways to communicate about research process, instead of just describing it.

D. Reflections on Generalizability

The contributions of participatory design research are deeply, permanently tied to the social context in which the research took place [30, 44]. In this way, design research generates *local* knowledge, informed by and situated in the values and social reality of the community involved [31, 45]. As Iversen explains, "designers and design researchers do not meet the world as clean slates. We bring with us values that shape our appreciation of situations, problems and potentials." Children think, learn, develop, and change through participation in their communities' sociocultural activities [53]. Therefore, future work should consider how children from *different communities* may have different perspectives on technology.

The perspectives of our workshop participants do not represent those of all children. Our participants were students at a school that has significant access to technology, including the robotics curriculum that initially brought researchers together with the school. Participants had a very positive emotional association with all technology, especially robotics. This perspective may not be shared by children from other communities; a difference grounded in factors that go much deeper than simply differences in resources. For example, children from a different community might have more visceral experiences with the effects of automation in industry or agriculture; alternatively, children who have experienced long-term hospitalization might have unique experiences (for better or worse) with technology in pediatric spaces.

Accordingly, the core contribution of our work is *methodological*. We show that co-design methods engage children in critical reflection as technology stakeholders. We do not claim that the content of our participants' reflection is universal. Instead, we encourage technologists to support children's reflexive practice about technology as it applies to the local, situated communities in which they explore the world. Future work in this space can help create a more diverse body of local knowledge by inviting other children, children from socially marginalized communities, and children with different personal life experience to also explore and reflect on technology ethics concepts.

VII. Conclusion

Children are stakeholders of robotic technologies who deserve to have their voices heard in the design process just as much as any other stakeholders. This is especially true for robotic technologies explicitly designed for child-robot interaction, in areas like education, healthcare, and therapy. Our research provides clear evidence that participatory design techniques can be an effective tool for involving children in this way.

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