Promoting Criticality through Design Futuring with Young Children

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ABSTRACT

As children's everyday interaction with emerging technologies increases, they need to develop criticality to navigate ethical impacts of technology and when imagining futures with technology. We explore how design futuring can facilitate children's criticality through four different workshops with children from India, Finland, and the USA. Participants imagined futures with technologies while critically considering ethical impacts. In the findings, themes related to empowerment and ethics emerged in children's imagined futures. We discuss promoting criticality and empowerment with children's imagined futures, and how these futures can respond to diverse, local issues based on their lived experiences. Our work diversifies design research by highlighting local futures, and the criticality of those imagined futures, from children across the world.

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CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Empirical studies in HCI; • **Social and professional topics** → User characteristics; Age; Children.

KEYWORDS

Children and AI, Child-centered AI, Design Futuring, Global South

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1 INTRODUCTION

As children increasingly use technologies for learning, entertainment, and to connect with their peers, the impact of such technologies on their everyday lives requires further scrutiny [46] [71]

[92]. For example, Artificial Intelligence (AI) and Machine Learning (ML) have well-documented cases of propagating biases and discrimination [38]. Novel technologies can perpetuate societal biases or benefit one group at the cost of another [2]. Because children increasingly use AI and ML systems in everyday life, scholars call for supporting children's critical perspective on technologies they use [47] [50] [67] [16]. Much of Child-Computer Interaction (CCI) research pursues an agenda of empowerment of children (e.g., [47] [90]). Scholars argue that efforts should go beyond educating children on technology use; children should also adopt a critical stance towards their own technology use and learn to critically imagine and design future technologies (e.g., [5] [25] [47] [50] [69]. Our work builds upon and advances this agenda through a series of workshops with children combining critical technology literacy and design futuring.

Prior work aiming to spark children's curiosity and critical questioning around technology has applied strategies such as friction and hacking (The Free Art and Technology Lab [76] [88]), and other critically-oriented design research approaches such as critical and speculative design [3] [47] [91] [83]. An agenda-setting review paper of CCI outlines the positive potential of this work, yet also highlights a need to focus more study on children's expressions of their critical perspectives on technology [47]. They call for greater focus on criticality in engagements with children, to work toward deeper, shared understanding of what criticality in design with children can and should entail. Our work responds to this call by analysing how children expressed critical perspectives around technology in four workshops.

We examine four different workshops that used design futuring approaches with children. The workshops were conducted with children ages 9-12 in India, Finland, and the US. In each workshop, children participated in hands-on design futuring activities imagining future technologies for their everyday lives on different topics: (1) with robots in India, (2) for a future school in Finland, (3) to reduce bullying at schools in Finland, and (4) how AI technologies might change learning in the US. We analyse children's imagined futures, surfacing how they express notions of empowerment and agency, critical perspectives on human-technology relationships, and mistakes and responsibility with future technologies.

This research investigates, *what critical perspectives do children express when imagining futures with technology?* To answer this question, we analyse the outcomes of the four workshops, with a focus on how criticality is manifested in the outcomes produced by children. We position criticality within different research streams engendering criticality and further characterise it from the viewpoint of ethics (e.g. [77]) and empowerment (e.g., [57]), as elaborated in Section 2.4. Through our focus on design futuring approaches with children in diverse contexts, we also contribute to research that seeks to diversify design futuring [2] [60] [42] [84] [85]. Further, we discuss how CCI researchers can embed criticality through design futuring for critical technology literacy with children.

The paper is organised as follows: Section 2 presents related work on design futuring with children and our theoretical lenses on criticality, ethics, and empowerment. Section 3 describes our research process. Section 4 presents findings from the four workshops, and section 5 discusses implications of our work for the CCI and Human Computer Interaction (HCI) design communities. In section 6, we conclude the paper.

2 RELATED WORK

We outline related work on fostering criticality with children (2.1), design futuring with children (2.2), technological literacy with children (2.3), and clarifying our lenses of criticality, ethics, and empowerment (2.4).

2.1 Fostering Criticality with Children

In CCI, a growing body of work advances an agenda of fostering criticality with children [47]. This work employs approaches such as Scandinavian participatory design, critical design or ethical design that derive inspiration from various critical traditions in social sciences, humanities, design or arts (e.g., [44] [45]). Such approaches have also featured in CCI research (e.g., [24] [50] [91] [92]). While the CCI studies and critical approaches employed in them build upon different traditions and thus may vary in their goals and underlying assumptions, on a general level they share a commitment for critically approaching the oppressing conditions of the status quo, and taking action to transform these conditions and to empower those oppressed [47].

CCI adapts these commitments in a variety of directions: First, some work focuses on critically exploring the current state of affairs, identifying different forms of exclusion, marginalisation or oppression as picturing in children's lives (for a review, see [47]). Second, some work directly involves children in activities aiming to create a more equal, inclusive, empowering world, through design approaches fostering critical transformations (e.g., [5] [50] [69] [91] [92]). Third, some work focuses on digital technology and involving children in critically analysing digital technology's societal impacts (e.g., [3] [5] [50] [69] [78] [79]).

Our work builds on and extends this third line of research with our focus on digital technology, engaging children in critically analysing emerging digital technology's societal impacts, through design futuring.

2.2 Design Futuring with Children

Design futuring is an area of critically-oriented design research [60]. Design futuring is an umbrella term that builds on critical design and speculative design and includes "a variety of approaches that leverage design to explore futures as a means to comment on—and potentially change—the present" ([60]: 399). Design futuring often aims to be emancipatory, critical, and reflective, though imperfectly so (e.g. [60]). Design futuring enables (re)envisioning futures, exploring alternatives, questioning, imagining, and investigating different futures [42] [60]. Overall, design futuring supports rich and varied ways of expressing critical perspectives in design (e.g., [47] [83] [91] [92]).

A range of existing work explores design futuring with children. Studies have explored environmental futures [23] [68], envisioned futures of schooling [28], identified fears and hopes towards social robots [78], reflected on emerging technologies [40] [58], and engaged children in sociocultural issues through children's design and making activities [94] [95] or museum exhibitions [19]. CCI often uses design fiction [10] to collaboratively explore emerging

technologies with children, e.g., with ML [3]. Others use Theatre of the Oppressed [11] [12] with design futuring to reflect on social issues such as bullying, encouraging children to envision bullying-free digital futures [83] [91]. Many of these works are inspired by participatory design and recognize that children operate in diverse creative modes that can differ significantly from the kinds of 'design' outputs typically valued by adult design researchers [54]. Overall, these projects encourage children to adopt a critical, reflective stance towards technology and imagining futures with technology (e.g., [83] [3] [91]), inviting them to also take action, using design and technology for making the world a better place (e.g., [58] [83] [92]).

Our work builds on this past work by doing design futuring with children in diverse contexts (India, Finland, USA) and specifically analysing the criticality as embedded in children's imagined futures.

2.3 Critical Technological Literacy with Children

Considering recent developments with technologies, there is an urgent need to foster critical awareness of ethical considerations and key competencies in novel technologies such as those relying on AI and ML [65]. Such competency is needed in every age group, because AI systems are increasingly used for making high-impact decisions in daily lives of adults [9] [33] and children [53] [80]. In fact, many applications using AI/ML are targeted at children, such as toy robots, chatbots, recommendation, and decision-making systems [89]. Other applications may also directly affect youth and children's futures: For example, a controversial AI model determined university entrance exams grades during the pandemic in the UK, which was rolled back due to systemic biases [38]. Recently, the state of Texas in the US is deploying a large language model to grade written responses on standardised tests for children aged 8 and higher [75].

As children encounter various technologies that impact their daily lives, a growing body of work aims to support children in gaining technical competencies, such as digital literacy and computational thinking skills (e.g., [22] [73] [74] [65] [93]). In CCI research, AI has been investigated in the context of child-robot interactions (e.g., [35] [36]) conversation agents [20] [27] [86] and recommendation systems [74], with more emerging work on decision-making systems [17] [37] [92]. In recent years, scholars have strived to support children's AI skills and literacy. The studies focus on various ethical and critical aspects, such as diversity [79], fairness [15] [16] [82], inclusion [24], societal impacts [97], and envisioning alternative futures [83].

We build on this related work with our workshops, combining technological literacy with design futuring, while our analysis in this paper focuses on the criticality emergent in children's imagined futures with technology.

2.4 Overview of our lens of criticality, ethics, and empowerment

To help clarify how ***criticality*** is interpreted in the research community, we outline three different views, which we loosely refer to as (i) inspired by the critical research tradition in social sciences and humanities, (ii) the critical thinking tradition, and (iii) critical design in arts and design traditions. It is important to note that we do not put forth these views (i, ii, iii) as definitive categories or as a complete set; rather, we simply aim to organise an outline of varied approaches to help situate and clarify our own approach.

First, the critical research tradition in social sciences and humanities underscores critiquing the oppressive conditions of the status quo and consequently redefining and transforming the present situation (e.g., [4]). To accomplish transformation, critical research should consider ways for empowerment and emancipation of the oppressed and aim to override the status quo, to "overcome injustice and alienation" [87]. This type of criticality has been discussed in CCI research, for example in calls for the empowerment of children [55] [56] [90] and in studies calling for critical design in CCI (e.g., [47]).

Second, criticality can also be approached in the sense of critical thinking (e.g., [47]. This tradition approaches criticality as "*the component skills of analyzing arguments, making inferences using inductive or deductive reasoning, judging or evaluating, and making decisions or solving problems*" [61]. In this sense, criticality relates to being analytical and logical, maintaining openness and fairness, fostering curiosity, and actively striving to be well-informed and well-reasoned [61]. There is CCI research promoting criticality also in this sense (e.g., [62]).

Third, perspectives within arts and design traditions provide another understanding of criticality. Bardzell and Bardzell [7], inspired by Dunne and Raby [30] [31], focused on criticality to foreground the ethics of design, reveal hidden agendas and values, explore alternative values, and challenge the prevailing status quo [7]. They draw inspiration from critical research traditions in social sciences and humanities (such as the Frankfurt School) but are not limited to it. Surprising, different, alternative, provoking, reflective, ethics-oriented design artefacts often characterise this type of criticality. Compared to the other two concepts, this approach to criticality has received less attention in CCI research, even though calls for it have emerged [44] [45] [47].

In this paper, we approach criticality mainly within the design and arts tradition, with our focus on how children envision futures with technologies, paying special attention to ethics and empowerment as expressed by children.

We acknowledge that ethics and empowerment are both concepts closely connected with criticality (see e.g., [4] [7] [8] [87]). They are both also complex concepts with a multitude of traditions and definitions associated with them (e.g., [77] [48]). In this study we approach ***ethics*** in an open manner to include considerations of what is morally wrong and what is morally right [77]. We approach ***empowerment*** generally as increased control and mastery for individual children or entire collectives over their own lives, i.e. having increased agency in the sense of capacity to act. Hence, empowerment can be approached both as an individual and collective construct [51] [48]. For example, past work has explored how critical making can support a sense of empowerment of self and others [39]. Using these lenses for ethics and empowerment, we focus our analysis on how children express considerations of what is morally wrong or right, and how children express imagined futures with greater empowerment.

3 PROCESS AND METHODS

This paper synthesises insights across four different workshops with children.

Selection of locations: The first three authors are from India, US, and Finland respectively, and this played a role on the selection of the locations. Given their own personal experiences with the schooling systems in these locations and their roots in these cultures, these authors also highlighted the cultural nuances during the analysis of the data. The selection of such culturally diverse locations is a novelty of this work. By combining the results of workshops from different locations–Finland, India, and the USA–each with varying goals and agendas, we showcase the rich and diverse ways children critically think about, imagine, and design for their futures. Our findings highlight the rich outcomes from across the different workshops, and we analyse how criticality emerged in the children's designs and discussions of their designs.

Selection of workshops. We analyse these workshops together because they all invite children to imagine alternative futures with technology and critically reflect on the social and ethical implications of these futures, working at the intersection of CCI (e.g., [64]) and design futuring [60]. Design futuring involves imagining and telling stories about alternative future possibilities as a way of critically considering the sociotechnical impacts and ethics of technology [60]. In all four workshops, researchers conducted hands-on workshops asking children to imagine alternative futures as a way of engaging children's interests and issues, following a recommendation for supporting genuine participation of children [18] [57]. The workshops sought to both help children gain particular learning competencies and develop outcomes such as props, puppets, or performances [57]. All workshops were designed and hosted as part of the authors' ongoing research collaboration. The workshops share overlapping researchers and facilitators and are motivated by a shared research agenda on empowering children to imagine and build their own ethical, equitable futures with technology.

Differences between the workshops: While each of the workshops focused on different future technological worlds, they all utilised design futuring to inspire, provoke, and motivate children to imagine future technologies in the context of their everyday (future) experiences. All workshops specifically invited participants to engage critically with their ideas and consider the ethical implications of their imagined future scenarios. Children's own cultural contexts impacted the workshop process and outcomes. With regards to the process, workshop #1 was conducted in a multilingual environment, where the moderator (who is Indian) used both Hindi and English, since children use both languages at school. Workshops #2 and #4 were conducted in English, where in workshop #2 children spoke various languages among themselves during the workshop (no data collected on this). Workshop #3 was conducted in Finnish. Regarding the outcomes, all participants were motivated and encouraged to imagine their own futures, building on their own lived experiences, which varied in each location. We did not collect data on the social background of the children, however, the school of the participating class in workshop #1 was a government school in a low-income area of the city, and participants in workshop #4, were from a minority community that the summer camp organisers (at the digital fabrication lab) reached out. Children in workshop #2 were from an International School. Workshop #3 was conducted at a public school in Finland, catering to the local population. Thus, children's background impacted the workshop outcomes (as discussed in 5.2). Workshop #3 did not specifically focus on AI; however, the imagined sociotechnical solutions inherently built on such AI-based technologies, and the workshop shared an emphasis on ethical criticality and imagination.

Next, section 3.1 provides an overview of the workshops. Our analysis, detailed in Section 4, focuses on what all these workshops have in common: Across the workshops, we analyse the alternative futures children imagined and the critical ethical considerations present in children's reflections on their imagined futures.

3.1 PROCESS AND METHODS

In this paper, we analyse the outcomes of four workshops - Robots, Future Teachers & Friends, Anti-bullying, and Puppets. For all the workshops, approval was granted and consent and assent were obtained from all relevant authorities, parents/guardians, and child participants, according to the requirements of the different locations and institutions. In each of the workshops, hands-on participatory activities were conducted with children. In all the workshops, we explored various ways to invite children to imagine alternative futures with technology, prompting criticality. We also prompted children's critical reflections through discussions about their imagined designs, when children presented or performed their ideas, and with Q&A from their teachers or other site-specific facilitators, asking children to consider both intended and unintended consequences of their imagined futures. We prompted children to consider how their designs would be fair, what their imagined future designs "*can and cannot do*", what might be some "*good things*" as well as some "*bad things*" that can happen, and what should happen in case the technology makes a mistake. The workshops and activities are described next.

Workshop #1 Robots: Imagining future everyday lives with robots: We engaged a 7th-grade class at a school in India. We introduced a variety of robots and AI through pictures, videos, and discussions, and interaction with the Nao v6 educational robot (Figure 1). The session was conducted during the school day at the school's digital fabrication lab, with the class teacher present.

Activities: Participants divided into three groups of 10-11. Each group participated in (a) block programming the Nao robot using Open Roberta Lab [72], (b) a drawing activity to speculate and design future robots (drawing on activity sheets in pairs) and (c) critically discussing the ethical implications of their designed robots in their everyday future lives, such as, what happens if the robot makes a mistake, and who is responsible for the damage and has to fix the issue?

Workshop #2 Future Teachers & Friends: Imagining future AI teachers and friends: The workshop was conducted during the autumn break in a Finnish child-friendly digital fabrication lab.

Activities: We introduced examples of AI in everyday life, such as YouTube recommendations, Google search results ranking, social media feeds, and voice assistants. Children explored the use of Teachable Machine [14], training it to distinguish between closeup images of chihuahuas vs. blueberry muffins. Children collaboratively generated prompts to try out Dall-E 2 [21]. In groups of

Table 1: Workshops analysed in this study. The activities of each workshop are summarised in the body text paragraphs. Participant gender is derived from their names and is not self-reported.

Participant demographics	Duration	Setting	Outcomes produced by children	Data analysed for this paper
(W1) Robots: Imagining future everyday lives with robots				
31 children age: 10-12 14 girls, 17 boys	3 hours on 1 day	New Delhi, India: In-person at a public school	Drawings and descriptions of imagined future robots	Drawings and descriptions, transcripts of discussions, researcher observations
(W2) Future Teachers & Friends: Imagining future AI teachers and friends				
15 children age: 9-12 6 girls, 9 boys	6 hours (3 hours on 2 consecutive days)	Finland: In-person at a city center digital fabrication lab	Drawings, descriptions, tangible prototypes, and group presentations of imagined future AI	Drawings and descriptions, transcripts of group presentations and discussions, researcher observations
(W3) Anti-Bullying: Imagining sociotechnical solutions against bullying in school				
22 children age: 11-12 8 girls, 11 boys	6.75 hours (9 weekly sessions, each 45 minutes)	Finland: In-person at a local school	Drawings, descriptions, tangible prototypes, and theatre skits of imagined future sociotechnical anti-bullying solutions, post-performance discussions	Drawings, descriptions, prototypes, transcripts of performances and discussions, researcher observations
(W4) Imagining future schools with puppets				
5 children age: 10-12 3 girls, 2 boys	3 hours on 1 day	US South: In-person at an all-ages community makerspace	Drawings, descriptions, tangible puppets, theatre skits of imagined future change for school	Drawings, descriptions, transcripts of performances and discussions, researcher observations

Figure 1: In Workshop #1, groups collaboratively working together with the Nao v6 educational robot.

3-5, they filled in worksheets asking them to imagine, draw, and describe a future AI entity such as a teacher or friend (Figure 2). Then they used laser cutters and/or 3D printers to create physical representations of their ideas. Then they presented their ideas to the other groups, and engaged in discussions reflecting on the ethical implications of their designs.

Workshop #3 Anti-Bullying: Imagining sociotechnical solutions against bullying in school: Children worked to develop sociotechnical anti-bullying solutions (e.g., robots, mobile applications) and reflected on bullying and technology from a critical perspective. The work started with collaboration with the city's education authorities who suggested the topic of bullying in school to be addressed in the project. Reducing and preventing bullying is one of the key targets of the city and frequently addressed in the public discourse in Finland due to severe bullying incidents in the country.

Activities: Activities started with a sensitising to bullying phase, followed by ideating, designing, making, and reflecting. All phases included several sessions, and children worked in groups of 3-5. Children engaged with the topics through letter writing, drawings, scenarios, and personas. They ideated and prototyped technology using arts and crafts materials and several different digital fabrication processes, such as laser cutting, 3D printing, vinyl cutting, during a visit to a digital fabrication lab in the city center (as a part of the workshop). In discussions, they critically reflected on their designs, and finally, presented their solutions using drama, more specifically, Theater of the Oppressed [11] [12] performances (Figure 3).

Workshop #4 Puppets: Imagining future schools with puppets: We hosted this with a child-friendly makerspace in a Southern US city during the summer break.

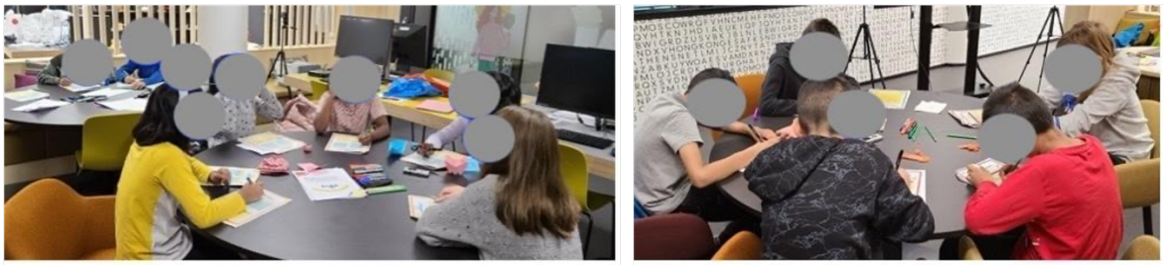

Figure 2: In Workshop #2, Participants discussing their future teachers and friends. (left) This group imagined a robot who could help with unburdening of domestic labour, while avoiding overreliance. (right) This group imagined a future currency within schools.

Figure 3: (left) In Workshop #3, children performing their solution of a robot which would increase empathy between pupils using "empathy stamps". (right) In Workshop #4, children performing their imagined future with an AI-enabled implanted brain chip.

Activities: In groups of 2-3, we asked children to imagine a "big idea" for changing the future of their school. Each group developed their own idea. We asked them to imagine what people might say in support of or against the idea, and to imagine a character who has an opinion about this idea. We introduced examples of AI in everyday life, such as YouTube recommendations, Google search results ranking, social media feeds, and voice assistants. We introduced ChatGPT and participants used a template to prompt ChatGPT to generate a script in which their characters debated their big idea. Participants created physical paper-and-rod puppets for their characters. We printed out the scripts and participants modified the scripts as they wished. Participants performed the scripts (Figure 3) and then discussed and critically reflected on their envisioned futures. Note, no ChatGPT-generated text is included in data for analysis or included in this paper, because our analytical focus is on how children imagined futures and critically considered societal and ethical impacts of those futures.

3.2 Participant Demographics

Participants in all workshops were ages 10-12. Each workshop had a roughly even split of genders. Workshop #1 had 31 children, ages 10-12, 14 girls, 17 boys. Workshop #2 had 15 children ages 9-12, 6 girls, 9 boys. Workshop #3 had 22 children ages 11-12, 8 girls, 11 boys. Workshop #4 had 5 children ages 10-12, 3 girls, 2 boys. This is summarised in Table 1. Workshop #2 allowed one 9-year-old to participate at the last minute when his parents brought him along with an older sibling. Workshop #3 had a slightly narrower age range because it took place as part of an existing class in a school, which had divided children into this age segment. Workshop #4 had a smaller number of participants because it took place during summer holidays when many local families with children may have been travelling. Workshops #1 and #3 were conducted with an entire classroom during an academic term and at a school, thus, the entire class participated. It is common to have 20-25 children in a classroom in Finland, while in India this number is usually higher (30-50). Workshops #2 and #4 were conducted during the holidays and in local city's digital fabrication labs. Participants (or their parents) had to sign up for these workshops and participants had to travel to the workshop venue. Thus, fewer children participated in these workshops compared with the ones conducted at schools. All workshops were free of charge, but participants were also not compensated for their time. Participants in workshops #2 and #4 were provided snacks during a snack break.

Rationale for age range of participants. We focused on the age group of 10-12 years old, because in this age most children are able to engage in hypothetical reasoning about abstract concepts or people in particular roles, even without concrete representations in front of them [34]. In more practical terms, in our workshops, children readily described hypothetical scenarios about people in particular social roles interacting with imagined future technologies (e.g., a sister interacting with a social robot to help care for a younger sibling, employees at a company being responsible for AI mistakes, or many other examples detailed in the findings). Ample prior work in critical data literacy and critical AI literacy demonstrates that

children aged 10-12 (or in overlapping age ranges) can engage in learning about data, AI, and ethics (e.g., [66] [79]. For example, past work engages children aged 10-13 in ethical reasoning about robots [1] drawing from theory of children's moral development showing that children in this age range are capable of moral reasoning [59]. Around age 12 we find diverging developing aspirations among children and how these might influence their future career choices [6]. It, thus, is a key age to engage students in STEM activities before any imposed perceived differentiation.

3.3 Data and Analysis

The data used for analysis for each workshop is outlined in Table 1 and detailed here.

- *Workshop #1* - participants' drawings and descriptions of imagined future robots were gathered, including transcripts of their discussions considering social and ethical impacts of these robots. This totalled about 15 sketches each with a few words describing it, and transcripts of about 90 minutes of audio. A researcher (also co-author) conducted the workshop in Hindi and English, fluent in both languages, and translated quotes from participants as needed.
- *Workshop #2* - data collection included drawings and descriptions of participants' imagined future AIs and transcripts of group presentations about their ideas, and post-presentation discussions on the social and ethical impacts of these ideas. This totalled about 7 design sketches with a few words of description each, and 24 minutes of audio. This workshop was in English.
- *Workshop #3* - participants' drawings, descriptions, and prototypes of their imagined anti-bullying solutions were gathered, including transcripts of performances showing their solutions, in addition to post-performance discussions reflecting on social and ethical impacts of these ideas. This totalled about 15 sketches with a few words of description each, and about 40 minutes of audio. A researcher (also co-author) fluent in Finnish and English, conducted the workshop in Finnish and translated participant quotes to English as needed.
- *Workshop #4* - participants' drawings and descriptions of their imagined future changes for school were gathered, including transcripts of performances describing these imagined futures, as well as discussions considering social and ethical impacts of these ideas. This totalled 2 performances with a few words of description each, and about 211 minutes of audio. The workshop was in English.

We used thematic analysis to surface emergent themes [13]. The researchers first analysed the data from the workshops they had helped run. Then, all emergent themes were compiled in a shared-online Excel sheet, where researchers iteratively coded and refined themes. Qualitative codes, with supporting quotes, were assembled in this shared spreadsheet for all the four workshops, combining and compiling the first round of coding. Throughout, researchers met online to discuss their analysis to maintain a shared understanding of the codes, collaboratively and iteratively refining them and synthesising emergent themes. The focus of our analysis, across all workshops, attends to criticality, ethics, and empowerment as expressed in children's imagined futures.

4 FINDINGS

Our findings detail how children imagined a variety of technological futures and critically reflected on social implications of these futures. They imagined empowered futures for themselves collectively as children at school, and also for themselves collectively in their living situations outside of school (section 4.1). As for ethical issues, they imagined future relationships between humans and technologies (4.2), and what should happen in case technologies made mistakes (4.3).

4.1 Imagining futures of empowerment and agency

In all workshops, children imagined futures of increased empowerment and agency, in various ways across geographical and socio-cultural backgrounds. Children imagined greater educational empowerment, financial agency, unburdening of domestic labour, and empowerment through emotional support. As introduced in related work (section 2.4), empowerment and agency are closely related, referring to increased control and capacity for action in one's own life, whether individually or collectively.

Educational empowerment and agency: One group of participants (W1), envisioned future robot-teachers specifically to support their classroom learning when teachers are absent (see Figure 4). As one participant described, "*a robot can help us if someday our faculty is on leave, it can explain our assignment to us, this way it will help in studies*". In the Indian context, teacher absenteeism is known to be an issue in government schools. Addressing this issue shows children's desire for improving their education, where their education is linked to their growth and empowerment.

Similarly, another group (W4) envisioned the ability for children to learn "*quantum physics in kindergarten*". They imagined "*a school where kids can choose what they learn, instead of just learning the same things that you don't want to learn*". This indicates a desire for greater agency in choosing subjects of study. This US group also imagined new subjects they would want to learn, suggesting "*maybe there's a class on astrophysics*". These children discussed finding their present-day classes too boring or easy. The US children are imagining from a different context and place. Still, relative to their position and coming from their perspective, they similarly imagined ways to improve and advance their education.

Another group in (W4) imagined AI-enabled brain chips that ensure that children automatically know how to do maths and how to read. They imagined this could help "*also reduce homelessness,*" linking education to being able to make money to afford housing. A participant from outside their group commented on their idea, "*I kind of wanted to mention, about the thing, about making education (available) for people with worse backgrounds and stuff. A lot of times those people wouldn't have as much money. And as you can imagine, these chips would probably be pretty expensive, and you might not be able to afford the chips*" (W1). These children imagined future technology to support education and the empowerment for a better life through education, and they also considered issues of

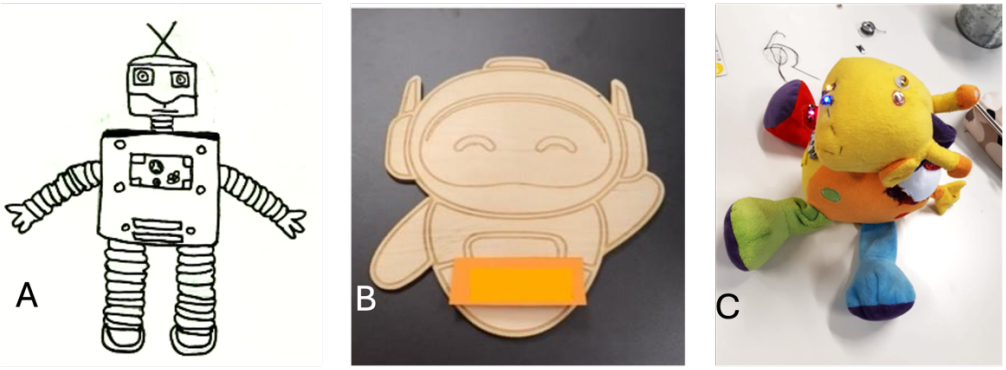

Figure 4: Future technologies as imagined by participants in India and Finland. (a) Children's imagined future robots that can teach and help with household chores. (b) Children imagined this robot would assist with domestic labour such as caregiving and housework.

who could afford this. This suggests valuing both empowerment through education and equitable access to education.

In both the India (W1) and US (W4) contexts, children imagined educational improvements for a plural "us" and "kids", thinking not only for themselves individually, but more collectively for children in their schools. This hints at an underlying desire for improving equitable access to education.

Financial agency: One group of all boys (W2) imagined a future currency distributed by a school-specific bank, both in digital and tangible forms (coins), for children at school to allow them to buy things that they need. This suggests a desire for greater agency in choosing what to buy and buying it oneself for procuring everyday needs. The children explained that, in this imagined future, all children start with the same amount of money, which can only be used by and for the children themselves, with a caveat that those "*who use the currency for bad purposes, will have their money removed*". These future child-only currencies underscore children's desire for financial agency and independence, where they can buy whatever they need, and they get to decide what that is. However, even in this materialistic scenario, children were clear about equal access - that all children in the school have access to this currency and start with the same amount. In this way, children considered agency, equal access, and responsibility

Empowerment through unburdening of domestic labour: Children imagined outsourcing a variety of everyday tasks to their future robots, reducing everyday domestic labour - not only themselves as children who are possibly cleaning their rooms, taking care of their younger siblings, helping with the cooking, gardening, and other domestic chores; but also as being part of a household where they are for example being driven around in a car. For example, children (W2) imagined a robot called *'Bob the Free Pod'* that can do everything for you, "*including cooking, showing videos, teaching*". A second group in (W2) imagined a domestic helper robot who would help with similar household chores. Children in (W1) imagined, "*we will make (the robot) do all the household chores*", and that robots can and should "*help us with anything such as cleaning, gardening, and driving*" (Figure 4).

Children also imagined robots assisting with caregiving. Children in (W1) imagined, *"[W]hen we're in school then our robot can play with the dog*", helping care for the dog in the child's absence. Similarly, another group (W2) imagined a robot that could help with caregiving (Figure 4). They envisioned a "*baby bot, which helps take care of babies and entertains them so it's a different type of bond*", again envisioning robots assisting with caregiving domestic labour.

In these ways, children imagined a form of empowerment through unburdening themselves and others in their household of chores, caregiving, and other domestic labour.

Empowerment through emotional support: Children imagined ways that future technologies could offer empowerment through emotional support. In the anti-bullying workshop (W3), children imagined ways that future technologies could create more supportive school environments. One group proposed an empathy robot (see Figure 4) which would "*stamp*" everyone entering school to increase empathy, creating a safe environment. As one participant exclaimed, "*all of a sudden, you are in a better mood. . . you are friendlier and more empathetic, and you understand how others might feel about bad words*". However, this would only work if everybody is stamped when entering the school, "*Otherwise, you cannot enter the school building*". Another group in this workshop imagined a size-changing anti-bullying police car, which provides entertainment for all by organising parties and other activities to create a cheerful atmosphere. With these ideas, children imagined a friendlier, more empathetic, more cheerful social environment. Bullying is extremely disempowering; these ideas envision empowerment through greater emotional support, to create an environment free from bullying. These imaginings also show how children considered individual student's emotions as entangled with the collective empowerment of the school. Further, many children described that the anti-bullying workshop (W3) helped them adopt another's perspective, saying *"[I learned] you should help if someone is being bullied*". Even in imagining future technologies, children tied their reflections back to present-day issues and what they can do in the present to help.

Children also imagined broader possibilities of emotional support. For example, children (W2) imagined that robots with AI

could "*see your emotions and help you when you're sad*", while participants in (W1) imagined that "*if a person has a robot and the person is depressed, then the robot can make them feel happy*". These participants suggest ways that AI could be used to help offer emotional support. Further, participants in (W1) imagined that humans could form emotional bonds with AI, describing, *"we can also share our secrets with the robots, they can be like our best friends*". This was further developed into imagining close supportive friendships: "*because (robots) help us. . . we (might) love them*", giving an example of how *"Doraemon was a robot"* that helped Nobita [26]. Thus, participants imagined how future technologies could offer greater emotional support. In a sense, increased emotional support can help increase empowerment, because having the support to navigate and process one's emotions can help with gaining control and capacity for action in one's life.

Summary: Across all the workshops, children imagined futures of greater empowerment and agency, in their education, financially, in domestic labour, and through emotional support. Their imagined ideas critiqued and sought to address local issues they experienced in their everyday lives, and envisioned greater support for themselves and their communities.

4.2 Considering ethics of human-technology relationships

Throughout the workshops, children critically reflected on the ethics of their imagined future technologies: Children considered ethics of (un)intended harms caused by technology or even to it, emotional risks, fear of over-reliance, and what should happen and who should be responsible in case of mistakes. As participants in (W1) said, "*robots should not use their power for bad things*", illustrating children's ethical considerations on what technology should and should not do.

(Un)intended harms from technology: When asked to reflect upon some good and bad things that can happen in their imagined futures, participants imagined how technology could be harmed or do harm accidentally.

Children imagined how technology could cause harm. For example, children in (W4) imagined that their AI-enabled implanted brain chip might "*malfunction and blast someone's brain*" by mistake, causing life-threatening accidental harm to the person (Figure 5b). In (W3) children imagined that their anti-bullying device might give "*electric shocks to innocent people*", when thinking about the worst-case scenarios of their solutions to mitigate bullying at schools (Figure 5a). Children in (W1) critically reflected on how robots could cause harm, *"(robots) can lose control and harm humans as well"*. In the discussion of a domestic robot taking care of their pet dog (described in section 4.1), participants expressed concerns ranging from "(*robots) can harm the dog*". Further, participants (W1) considered how technology might impact other species beyond pets; "*animals, (and) birds can be harmed (too)*" and *"(robots can) harm the environment*". Children articulated a variety of harms that technology could cause.

Children also considered how robots could be harmed. For example, when considering a robot caring for a pet dog (W1), children imagined that "*dogs can also harm the robots (while playing)*". Children expressed concerns about a future scenario where robots take their pet dogs for a walk, in which "*robots might not know the ways and the roads or how to walk [on complex Indian roads]*." This could be dangerous because "*robots can come under cars while crossing the roads"*. This suggests their awareness that robots may be limited in their ability to navigate a complex and multispecies world, which could lead to harm for the robot or for other beings or the environment.

Overall, participants imagined that future technologies could have imperfect understandings of the human world or accidentally lose control, which could lead to causing accidental harm to children, other people, animals, the environment, and even the technologies themselves. Such insights reveal a rich level of reflection on human and more-than-human relationships with technology.

Emotional risks in relationships with technology: Participants also considered that emotional relationships with technology could entail risks. For example, participants in (W1), who imagined future robots helping care for pet dogs, also worried that if the relationship between robot and dog became too close; " *then what if (the) robot prefers the dog*" and "*slowly (our) dog will forget us*", or if "*the dog gets attached to the robot and the robot (leaves), the dog will feel bad*". These imagined futures suggest risks in forming emotional bonds with anthropomorphised technologies.

Children in (W1) also imagined risks with robots displaying emotions. They said, "*we should also know that robots have feelings*", and imagined one way this could be expressed as "*reflected through (the robots') eyes*". For example, they imagined, "*when in anger, robot's eyes turn red*", and imagined this as an undesirable, unpleasant possibility.

Participants in (W3) considered how their imagined anti-bullying technologies might, instead of increasing empathy, spread sorrow and negative feelings, especially if the robot gave punishments to the person bullying instead of taking an empathetic approach and providing resources for supporting the bully. Children critically reflected on how their designs for robots intervening in anti-bullying contexts also came with risks of unintended emotional or even physical harm. A group describes a dystopian scenario when the technology is not functioning as planned: *"The robot has had a software failure and is forcing people to bully. Because of which people don't think about anyone but themselves . . . ".*

Fear of over-reliance: While several groups (W1 & W2) discussed the unburdening of domestic chores to robots (described in section 4.1), they were also critical on how much should be offloaded. The group which imagined a baby-bot and other domestic helpers, warned that there should be limits, saying, "*sometimes, you can't always rely on the robot, you can't always make the robot do something"*, exclaiming, "*you also have to do something*", "*you can't just sit around and tell the robot to do this or that*". They envisioned a human-robot partnership for domestic labour, alluding to humans remaining in control, that domestic robots should assist with and work alongside household members, lessening the burden but not replacing human labour altogether. Similar perspectives were shared by children (W1) who reasoned that such limits will ensure that "*humans (do not) become lazy*". They further corroborated that robots should "*listen to (and do) the assigned work. Be in control of the owner"*. Here again, children reflected on the possibility of humans being over reliant on robots in the future and how humans need to be in control.

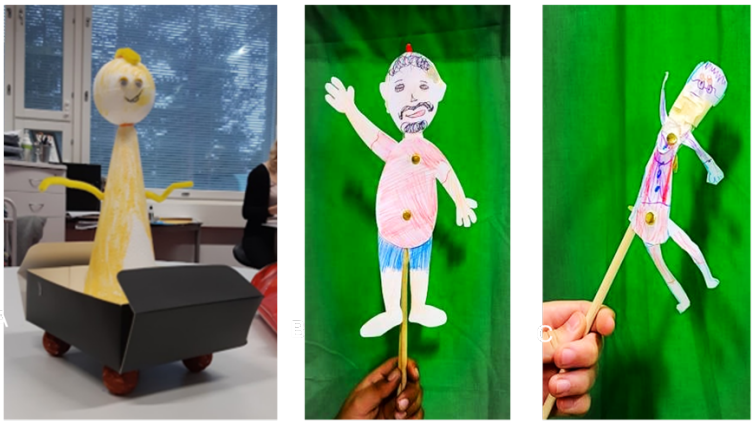

Figure 5: (a) Participants imagined that a robot would give electric shocks to those who bully as a form of punishment and to stop the bullying (W2), (b) A puppet character (W4) who was critical of an AI-enabled implanted brain chip, yet in a dystopian plot twist.

These findings, drawn across different workshops, illustrate children's ability to imagine a range of critical and ethical perspectives towards human and more-than-human relationships, including (un)intended harms, emotional risks, and possibility of over-reliance. They also demonstrate participants' emerging critical literacy that not only considers the limitations of a single technology, but that draws connections to other social or environmental factors, and includes the characteristics of the technology itself.

Addressing and preventing mistakes. Children critically considered the ethics of what should happen in case the technology made mistakes, and how to prevent mistakes.

Children considered what to do when robots made mistakes. As one participant explained in (W2), "*We [users] have to try to understand what happened exactly, and then if it's something very serious, we can bring it back to the company and they're going to try to fix it*". For an immediate solution, they continued, "*we could just shut it down*". Another child in (W2) imagined robots can be quickly disabled and turned off if there are any mistakes, which will mitigate any future damage. This suggests a reasonable approach of broadening the circle involved in addressing mistakes: In the immediate short term if needed, the technology should be disabled or turned off to prevent further damage. Then, users should try to diagnose what happened. If the mistake is very serious, the technology can be sent back to the company to be fixed.

Children suggested ways to try to prevent technological mistakes. For example, humans should try to prevent technology from making mistakes by ensuring that technology "*should do stuff that humans can control if it goes wrong*" (W2). One pair (W1) mentioned in their designs that their future robots will only do the things they program it to do and "*will not perform those things which we haven't programmed*", as a means of avoiding mistakes. One group that designed a robot to reward and punish people related to bullying (W3) explained that "*there has to be a person, who controls the robot team, to prevent any programming errors*" so that the robot does not accidentally punish the wrong people. One participant in (W1) speculated that maybe "*there should be a function where robots can think about (their actions)*", to help prevent mistakes. Overall, preventing mistakes was considered mostly humans' responsibility, though artificial intelligence could also learn to "*think*" about its actions to help prevent mistakes.

Some groups imagined that mistakes could be entirely eliminated, that the technology "*cannot make any mistakes,*" insisting that it cannot damage or destroy anything because *"it doesn't even have arms or guns built-in*" (W2). This group imagined that it cannot be "*hacked or corrupted*" because *that* robot's security comes from NASA, "*because NASA gave all of their security to (us)*" (W2), associating NASA with having very good security and error prevention. Here, preventing mistakes comes from a combination of limiting the technology's capabilities (no arms or guns) and adopting strong security practices from a reputable authority.

Handling and preventing technological mistakes is an area of ongoing societal, ethical, and policy debate. Children demonstrated that they could reason about responsibility in case of mistakes, while suggesting that a variety of different stakeholders could be responsible (e.g., user, designer/developer, government agencies). They almost exclusively located responsibility with the humans involved, believing that technology is within human control. The reliance on a larger entity (e.g., NASA for some participants in Finland) to provide security might indicate limitations of the reflection. Children might question the operation of technologies but not yet that of larger institutions (NASA, government, schools). Overall, most participants envisioned preventing mistakes through human control.

Responsibility. Regarding who should be responsible when technology makes mistakes, the only consensus was that the technology itself cannot be responsible.

Across all workshops, participants positioned technology as machines that humans are responsible for. Children in (W1) discussed how humans are responsible for robots' actions and the consequences of those actions, even if robots could possibly think about their actions. As one participant explained (W1), the robot is not responsible, rather responsibility lies with the "*owner, because he is*

controlling the robot, and (the) robot is just a machine". As another group elaborated (W2), "*humans should be in control. Humans are living things*". Children placed the control on humans and did not expect machines to be responsible for their actions (because they were "*programmed*" to do so). While children clearly suggested that technologies cannot themselves be responsible, and that humans should be responsible, what is less clear is who or which humans are accountable. Children suggested various possibilities such as the users of the machines, the companies that make and sell them, or the designers and developers who imagined and created them.

Summary. Overall, children' imagined futures, and discussions around their imagined futures, show a range of critical ethical considerations about what should and should not happen with technology. In considering unintended harms, children considered how robots may be limited in their ability to navigate a complex and multispecies world, which could lead to harm for humans, animals, and the robot. In forming emotional bonds with robots, there could be emotional risks. In delegating household tasks to robots, there could be ethical concerns of over-reliance on robots. Children suggested a variety of strategies for addressing and preventing mistakes. As for responsibility, children mostly considered that humans (in a variety of roles) must be responsible in case of technological mistakes.

5 DISCUSSION

For this paper, we analysed participants' designs and imaginings of future technologies from four different workshops in India, Finland, and the US, where children imagined future everyday robots (W1), future friends and teachers at school (W2), solutions for mitigating and addressing bullying at schools (W3), and how AI technologies might change learning (W4). Next, we discuss how children embedded critically in their future imaginaries (5.1) and how they underscored diverse, inclusive, local futures (5.2), revealing their critical understanding of the challenges in their everyday lives. Then, we discuss the implications of our findings to CCI research (5.3).

5.1 Children cultivating criticality and empowerment

Our findings show that children are capable of integrating criticality to design futuring in versatile ways. The children's future imaginaries illustrate how children critically reflected on future human-machine relationships and their social impact, envisioning futures of empowerment. Children imagined ways in which future technologies could support greater empowerment in their lives and education - for instance, with robot teachers (W1) and advanced educational topics (W4). They also envisioned being empowered in the future with robots doing everyday chores such as cleaning, cooking, and even childcare (W1, W2), but were critical and cautious about how much and what is outsourced to future robots so that humans stay in control and do not become lazy (W1, W2). In our cases, the focus on ethical issues is not that surprising as we prompted children to discuss them. Still, we were surprised to see the prevalence of empowerment in children's creations. Children in our study also had a strong sense of advocacy for empowerment of the oppressed – with imagined futures that integrate criticality in the sense of the critical research tradition in social sciences and humanities (e.g., [4] [87]). We also acknowledge no clear-cut distinction between these traditions can be made - there are many different interpretations and nuances in criticality and being aware of them helps us make appropriate choices when planning our design and educational sessions with children. Our findings show how children prioritised increased control of individual children or entire collectives over their lives. They clearly acknowledged both individual and collective empowerment. For instance, children considered solutions for homelessness (W4), for off-loading household to robots (W1, W2), and for their own personal financial agency (W2). We see value in children considering empowerment beyond the self, i.e., empowerment of others and larger collectives with increased feeling of social responsibility (see [39] [51] [47]). Our work underscores how empowerment and ethics emerged as prominent themes among children. We consider these themes appropriate when aiming at criticality - both concepts are closely connected with criticality (e.g., [4] [7] [87]) - while certainly these are not the only themes that could be addressed.

While existing work in CCI combining technological literacy and criticality focuses on present-day or near-future technologies. In our workshops, children imagined far-future and wider alternatives, considering not only typical technologies of today, but imagining emerging technologies and envisioning alternative futures that are ethical and empowering for them. Through our work, we add to a small but growing body of research in CCI that invites children to imagine and envision more empowering, equitable, and inclusive worlds (e.g., [5] [50] [69] [91] [92]). Our work adds to this previous research by bringing in a stronger futures orientation with criticality explicitly addressed as well as by inviting in voices of younger children across different cultural and geographical locations, most of whom are underrepresented in CCI research.

5.2 Children envisioning diverse, inclusive, local futures

Through our work, we underscore that children often remain grounded in solving local challenges within their communities, stemming from their everyday experiences. Children critically scrutinised existing conditions, actively designed speculative alternatives, and presented diverse viewpoints to their own designs. For example, children in India imagined that robots could step in as substitute teachers, solving a prevalent teacher absenteeism crisis (see e.g., [70]). While imaginations of future robot teachers are not globally novel, the uniqueness in this case lies in the local problem Indian children were solving with these imaginaries for their future selves. Similarly, US children (W4) imagined how microchips embedded into all children' brains might level the playing field when it comes to learning in the classroom, where getting an education was equated with adult employment opportunities and avoiding homelessness, a prevalent issue in the US (e.g., [63] [52] [41]). Further, American children's aspiration to learn difficult STEM topics, such as, quantum physics in kindergarden, also address current challenges the children face in learning about advanced STEM topics in school, since they live in the US deep south. For context, public schools in the conservative leaning US deep South (such as in Atlanta) struggle to teach STEM education, for example, children

might not be taught about evolution in school [49]. In Finland (W3), children imagined helping not only victims of bullying but also the bullies themselves, offering emotional support to help bullies improve their behaviour towards others and remain integrated in society; this focus on rehabilitation instead of punishment in some ways echoes Finland's approach towards criminal justice. Furthermore, this approach towards bullying also resonates with Finnish nationwide Kiva Koulu anti-bullying program that children were familiar with [43] [98]. Thus, in their envisioned futures, children were solving problems that they experienced in their everyday lives, stemming from the political, infrastructural, or social backgrounds of their unique cultural contexts. For these unique problems, they imagined similar solutions, robots as teachers and caregivers, access to more technology at individual levels, resources provided by governments and schools. While the children's imaginaries seem to echo similar sentiments as heard from adults working on educational technology, that is, robot teachers that can provide education for all, reducing teaching labour and providing personalized assignments and assessments [96]. The children also present other critical perspectives, such as, the role of humans in these scenarios and what future human-machine relationships could entail. Our workshops, thus, also enbale studying alternative imaginaries beyond mainstream narratives. With this work, we enable children to not only "join the conversation" related to pre-existing visions of technology futures, but we put them in the drivers' seat, inviting them to imagine the future directions that are best for their everyday situations and local communities.

5.3 Implications to CCI research

With children's increasing use of emerging technologies in their everyday lives, CCI researchers are working on cultivating and encouraging a critical mindset towards their use and design [22] [65] [73]. Considering both risks and benefits of future technologies is important for the integration of emerging technology into education to counter dominant rhetoric from the tech industry or media portraying technological innovation as mostly positive. Recent focus has shifted towards AI/ML literacy, with researchers exploring ethical and societal implications of AI technologies in children's lives. For instance, Schapers et al. [79] encouraged children to imagine a future robot president and critically consider the social and ethical implications. Similar to our work, they discuss cultural diversity and ethical social futures with children. Other CCI work has also used similar future imagining to discuss concepts of fairness in AI systems [16] [82] and technology inclusion [24]. Imagining the potential benefits and risks of future AI/ML is a key competency of AI literacy, as outlined by Long and Magerko [65].

We recommend that CCI researchers cultivate criticality in technology education of children while paying attention to which form of criticality they aim to advocate. In CCI research, criticality is too often discussed without elaboration of what it means. Even if we already positioned our study to approach criticality within the design and arts tradition (e.g., [7] [29] [30]), we can see the children in our study, with their strong advocacy for empowerment of the oppressed, to integrate criticality in the sense of the critical research tradition in social sciences and humanities (e.g., [4] [87]). We also acknowledge that there is no clear-cut distinction between these traditions. We emphasize that there are many different interpretations and nuances in criticality for CCI researchers. Being aware of them helps us make appropriate choices when planning our design and educational sessions with children. Our study also shows how empowerment and ethics emerged as prominent themes among children. We consider these themes appropriate when aiming at criticality - both concepts are closely connected with criticality (e.g., [4] [29] [87]), but certainly not the only themes that could be addressed.

We also recommend that CCI researchers invite children to envision diverse, local futures responding to issues in their everyday lives. This is important because envisioning diverse, local futures can have potential to impact children's everyday lives. Such an approach is valuable also as it supports the inclusion of different kinds of learners in computing education - learners are invited to leverage their local cultural knowledge and expertise, emphasised in the literature on genuine participation of children [57] and culturally responsive computing education [81]. Envisioning more diverse, local futures has also been called for in recent work in design futuring [42] and more broadly [32]. Through our work, we build a case for inviting children to imagine diverse empowering futures grounded in their own local, lived experiences and cultural knowledge. With this, children can critically engage in sociocultural issues that matter to them the most, making the world a better place for themselves and for everyone.

6 CONCLUSION

Our paper explores how design futuring can facilitate children's criticality through four different workshops with children from India, Finland, and the USA. Children imagined futures of empowerment and agency, and considered ethics of human-technology relationships. We discuss the benefits of embedding criticality through design futuring approaches in activities with children, where children are invited to envision diverse, alternative, inclusive, local futures. In our work, criticality pictured in various ways in the children's future imaginaries, where children envisioned empowering futures for themselves, and for society at large. Through these futures, children were also responding to diverse, local issues based on their lived experiences. Our work contributes to diversifying design futuring by highlighting local futures with children across the world. We encourage CCI researchers to invite children to critically engage in sociocultural issues that matter to them the most and envision diverse alternative futures that make the world a better place for themselves and for everyone.

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