Designing Together, Miles Apart: A Longitudinal Tabletop Telepresence Adventure in Online Co-Design with Children

Casey Lee Hunt
casey.hunt@colorado.edu
University of Colorado Boulder
Boulder, Colorado, USA

Kaiwen Sun
kwsun@umich.edu
University of Michigan
Ann Arbor, Michigan, USA

Zahra Dhuliawala
zahra.dhuliawala@gmail.com
University of Maryland
College Park, Maryland, USA

Fumi Tsukiyama
Iva Matkovic
Anastasia Wolf
fumi.tsukiyama@gmail.com
iiva@uw.edu
anastasialucas1@gmail.com
University of Washington
Seattle, Washington, USA

Zachary Schwemler
zasc5196@colorado.edu
University of Colorado Boulder
Boulder, Colorado, USA

Zihao Zhang
zz2830@columbia.edu
Columbia University
New York, New York, USA

Allison Druin
Amanda Huynh
adruin@pratt.edu
ahuynh16@pratt.edu
Pratt Institute
Brooklyn, New York, USA

Daniel Leithinger
daniel.leithinger@gmail.com
University of Colorado Boulder
Boulder, Colorado, USA

Jason Yip
jcyip@uw.edu
University of Washington
Seattle, Washington, USA

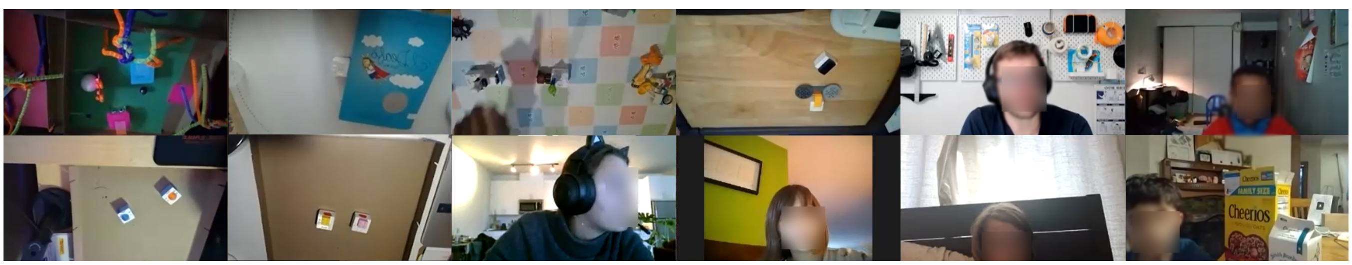


Figure 1: KidsTeam UW telling stories using the tabletop robots in co-design session 7.

ABSTRACT

Children's online co-design has become prevalent since COVID-19. However, related research focuses on insights gained across several shorter-term projects, rather than longitudinal investigations. To explore longitudinal co-design online, we engaged in participatory design with children (ages 8 - 12) for 20 sessions in two years on a single project: an online collaboration platform with tabletop telepresence robots. We found that (1) the online technology space required children to play a role as technology managers and troubleshooters, (2) the home setting shaped online social dynamics, and (3) providing children the ability to choose their design techniques prevented gridlock from situational uncertainties. We discuss how each finding resulted from interplay between our long-term technology design and online co-design processes. We then present insights about the future of online co-design, a conceptual model for longitudinal co-design online, and describe opportunities for further longitudinal online co-design research to generate new methods, techniques, and theories.

This work is licensed under a Creative Commons Attribution International 4.0 License.

IDC '23, June 19–23, 2023, Chicago, IL, USA

© 2023 Copyright held by the owner/author(s).

ACM ISBN 979-8-4007-0131-3/23/06.
https://doi.org/10.1145/3585088.3589359

CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; **Haptic devices**.

KEYWORDS

Participatory design; Children; Design methods; Actuated tangible user interfaces; Physical telepresence

ACM Reference Format:
Casey Lee Hunt, Kaiwen Sun, Zahra Dhuliawala, Fumi Tsukiyama, Iva Matkovic, Anastasia Wolf, Zachary Schwemler, Zihao Zhang, Allison Druin, Amanda Huynh, Daniel Leithinger, and Jason Yip. 2023. Designing Together, Miles Apart: A Longitudinal Tabletop Telepresence Adventure in Online Co-Design with Children. In *Interaction Design and Children (IDC '23), June 19–23, 2023, Chicago, IL, USA.* ACM, New York, NY, USA, 16 pages. https://doi.org/10.1145/3585088.3589359

1 INTRODUCTION

Co-designing with children has been a popular and important topic in the child-computer interaction community since the 1990s [19–21]. While traditional means of co-design are primarily local and in-person, recent research has pointed to the need to consider co-design with children in online spaces [22, 36, 54, 63, 71–73, 76, 77]. More recently from 2020 to 2022, COVID-19 shifted co-design online to the forefront [22, 36, 54, 76]. A number of papers have shown the need for adapting to co-design online with children [36], with special interest to whole body interactions [54] and socio-emotional experiences in remote co-design [76]. However, this recent online co-design research has only focused on the evaluation of engagements over a series of short term projects, rather than across a single design over time. For instance, Lee et al. [36] developed a conceptual model of improvisation in children's online co-design from analysis of 10 sessions across several design projects. Similarly, Fails et al.'s [22] comparison of three online co-design sites studied the process of co-design online during COVID-19, but had no emphasis on what was designed. While COVID-19 created a need for children's co-design online, the corresponding participatory design (PD) methodology has been understudied. We have little to no knowledge of online co-design techniques as they pertain to longitudinal work. Meanwhile, past in-person longitudinal co-design projects resulted in new design theories, methods, and techniques [19, 20, 79, 81]. For instance, the *International Digital Children's Library* [19–21] and *Science Everywhere* [1, 2, 12, 46, 79, 81] are two examples of co-designing with children for a period of months and years on a single project. Both research designs engaged in extensive work with children as users, testers, informants, and design partners [1, 21]. Inspired by these online short-term and in-person longitudinal co-design works, we set out to explore the longitudinal online co-design context with children.

The shift to remote collaboration presents challenges to online co-designers as certain in-person co-design techniques become limited; especially physically proximal activities such as crafting prototypes, acting out scenarios, and movement games to generate ideas. Therefore, remote interaction presents barriers for children's creative and collaborative expression, motivating us to explore a technical intervention to improve physical collaborations in online co-design. Building on work that studied tabletop telepresence robots for physical telepresence in remote collaboration [39, 62], we set out to co-design this technology for children. During this longitudinal online co-design, we explored two research questions: (1) *What kinds of opportunities and challenges emerge in a long-term online co-design process of a single product?* and (2) *How does children's long-term design and use of a tabletop telepresence robot collaboration platform impact online co-design processes?*

We studied these questions across approximately two years with 13 children (ages 8-12) at the KidsTeam UW intergenerational participatory design (PD) team through design prompts centering the telepresence robots (Sony Toio), which children controlled in near-real time through a web application. Our findings, situated in the unique longitudinal online co-design context, show three major themes around how (1) the technical space of online co-design presents persistent challenges, while the addition of the robots increases collaboration and shared-ownership of physical projects; (2) the social landscape of longitudinal online co-design in children's home affords both distraction and inspiration, while adding robots to the home facilitated social connections and playfulness between co-designers; and (3) the need to give children flexibility to adapt their use of co-design methods and techniques over time, including the versatility that emerged in children's use of the robots. These findings support previously identified characteristics of online co-design [22, 36], while contributing insights about the progression of these characteristics over a long-term collaboration and the strategies that emerged to adapt to the unique qualities of online co-design with children. We also present a conceptual model of longitudinal online co-design that describes the interplay between the design of the technology (tabletop telepresence robots) and online co-design processes. We then identify and discuss opportunities for further research of longitudinal online co-design, including the generation of new PD methods, techniques, and theories.

2 LITERATURE REVIEW

2.1 Children as Design Partners in Online Spaces

Participatory design (PD) centers the collaborative and democratic engagement of users in the design process [17, 31]. Inclusion of users in the design process can both empower users [83], and produce viable designs [1, 20]. Similarly, co-design refers to how experts work directly with end-users to solve a specific design problem. Our project specifically utilized a PD method called Cooperative Inquiry [20, 83]. Druin developed Cooperative Inquiry as a way for children and adults to be equitable and equal design partners [19, 20]. Children are experts at being children, and co-designing with them results in design products that fit within the childhood experience and context. However, despite children's knowledge, it does take time and effort to sustain relationships with them and build their design expertise [83]. Therefore, researchers utilizing Cooperative Inquiry often work closely with a smaller group of children over a longer period of time [19]. Researchers engaged in Cooperative Inquiry often study the development of design techniques to support balanced design between children and adults [81, 83]. A design technique is a series of activities that help designers communicate and collaborate with users [75]. Walsh et al. [75] notes that technique selection and development help designers consider the opportunities, challenges, and design constraints of each approach for their application.

Many co-designs with children occur in labs [83], libraries [35, 80, 82], schools [13, 24, 45, 57], community centers [16–18], and refugee camps [3]. Online, researchers have explored PD on social media sites like Facebook [41] or game spaces like Minecraft

[71, 72]. Additionally, some researchers have looked at asynchronous remote communities—through team chat protocols like Slack or Discord—as a way to encourage participation of distributed populations [7, 41, 44]. Since March 2020 and the emergence of COVID-19, more research with children and PD exists now in the online space, relying on Zoom calls for online co-design [22, 77]. Researchers use such platforms to create techniques for whole-body interaction online [54], and facilitate children's co-design around socio-emotional experiences [76].

More recently, Lee et al.'s [36] research focused on HCI improvisation as a way to make sense of online co-design considerations. They explored how online co-design interactions are about managing and taking risks, particularly when remote settings lead to a lack of clarity, certainty, and structure. Synchronous co-design online puts design partners in numerous challenges and pitfalls. Through HCI improvisation, online co-design can be seen as inviting new ways to be exploratory (reflexivity), flexible (transgression), and nuanced (tensions); considering how situations change quickly (listening), and understanding the context of the situation (interdependence). While we have learned much about online co-design with children and adults in recent years due to COVID-19, there is a gap-in-knowledge to consider. Lee et al. [36] and other remote co-design studies [22, 54, 63, 71–73, 76, 77] focus much of their analysis of online interactions on piecemeal shorter-term projects. That is, none of the studies and interactions in online co-design set out on a specific longer-term project with frequent iterations, testing, and incremental improvements over time. Shorter term projects online include one to two sessions [76], or multiple (three to five) online workshops [36, 44, 74, 77].

However, within the IDC and HCI space, there is a tradition of studying co-design longitudinally, as the design process can be more deeply understood given the length of time it takes for a design team to become skilled with the methods and techniques. For instance, the work of the *International Digital Children's Library (ICDL)* [19–21] and *Science Everywhere* [1, 2, 12, 46, 79, 81] focused on co-design projects that took place over years to generate new theories and methods about co-design [19, 20, 79, 81]. Online collaborations and co-design are more recent innovations, and we found no related studies that looked at projects taking place over a longer duration (months to years). Therefore, it is difficult to understand the specific nuances of online co-design as children develop over time. For this study, we examined 20 online / hybrid sessions (Appendix A.2) with children over two years to design a tabletop telepresence robot interface.

2.2 Telepresence for Remote Collaboration with Children

Prior work in HCI has explored how challenging co-working on tangible objects can be when teams are not co-located [9]. While synchronous video brings improvement to communication [32] especially when the task-space is visible on camera [8], it remains limited, especially for physically distant teams conducting creative work. Technology designs for remote collaboration have primarily focused on facilitating two key elements of successful creative work: social presence and shared context. Social presence interventions enable bodily presence within remote co-working spaces, facilitating the exchange of relational cues between coworkers' to build trust [37]. For example, telepresence robots have been used in a variety of configurations to provide shared presence within co-working environments [4, 69]. This approach has been shown to improve a user's sense of social presence–for both the party represented by a robot and the party interacting with the robotic actor [55, 61]. Meanwhile, the lack of spatial cues in video conferencing makes it difficult to communicate and ideate with physical artifacts, reducing the effectiveness of remote co-working sessions [64]. Shared context interventions facilitate the shared understanding of objects and spaces of interest to remote co-working tasks. Previous research has explored the use of shared virtual spaces [26, 34], alternative camera and video placement [50], behavioral interventions [23, 29], robots [51, 53], and actuated devices [9, 38] to create shared context through alternative representations of physical objects.

Considering the importance of social presence and shared context in online collaboration, prior work has explored how tabletop robots could support such needs during remote synchronous work. For instance, RobotPHONE created an actuated tangible element for users to communicate shapes during co-working, providing a shared representation for remote collaborators to see and feel each other's work [62]. Another project, ASTEROIDS, utilized tabletop swarm robots with attached cameras to allow remote users interact with the work of an instructor on a workbench scale [39]. Through this responsive, real time engagement, teams are able to build trust and shared understanding. Either through a shared representation, in the case of RobotPHONE or through distributed tabletop robots, in the case of ASTEROIDS.

Previous works have also explored how children might engage in more meaningful video conferencing with technologies that support social presence [10, 70] and shared context [30, 56, 78]. Such platforms, primarily explored in educational and familial settings, employed similar strategies to telepresence platforms built for adults' physical design collaboration, while considering the unique technical obstacles and social context of children. For example, ShareTable [78], a project designed to connect families from divorced households, provided users with an alternative viewpoint through a tabletop video feed and projection. Users could draw pictures on the same table, read books, or play games together, creating an increased sense of connection and expression. Tsoi et. al. designed a system that allowed users to log into an application to control the movements of a Vector commercial robot located in a child's home to explore remote synchronous communication [68]. Tele-operators could see the live camera stream from the robot, and actuate the robot through a variety of controls. This project primarily focused on using the robots to enable social presence between children and their friends and family.

Inspired by these works that improved remote communication and collaboration for children, and by tabletop telepresence technologies that facilitate both shared context and social presence in remote collaboration, we identified a tabletop robot platform that would adapt well to our context – Sony Toio. These commercially available robot toys with developer support have previously been used to build haptic and tangible tabletop interfaces [48, 49, 67]. In our work, we explore how the Toio tabletop robots might be used for synchronous communication in online co-design with children.

3 METHODS

3.1 Case Study

For this paper, we employed the case study method [43] to examine a single co-design project from March 2020 to May 2022. We investigated the two-year project at KidsTeam UW, an intergenerational co-design team of children and adults affiliated with a higher education institution [83]. This exploration is unique in three aspects. First, KidsTeam UW is an extreme case in both context and makeup. During the COVID-19 pandemic, most of the world was locked down in a once-in-a-lifetime event, forcing everyone to interact in mostly online spaces. This unique circumstance allowed us to examine our project in a remote PD team that had gone online during the COVID-19 lockdown. Second, this project is a revelatory case as it spanned 26 months, providing a unique opportunity to observe and analyze the understudied phenomenon of online co-design with children. Finally, the longitudinal characteristic of the project at KidsTeam UW demonstrated how situations and processes change over time on a single design and allowed us an in-depth understanding of how engagements unfolded in PD sessions that influenced the final design. We chose to work with KidsTeam UW to co-design the tabletop robot platform and evaluate longitudinal online co-design experiences of children during COVID-19 because the group had already established the participants, logistics, and resources to support a long term online co-design project. The KidsTeam UW cohort we worked with in this project consisted of a PD team of 13 children (ages 8 - 12), 7 designers and researchers (child-computer interaction, computer science, product design), and 24 adult volunteers for a total of 44 co-designers across 4 time zones and 5 institutions.

3.2 Contexts and Participants

KidsTeam UW occurred online from March 2020 to May 2022. We chose children ages 8 - 12 because this age group is developmentally ready for co-design but still able to be child-like (see Recruitment of Participants statement). We recruited for diversity in ethnicity, socioeconomic status, gender, and age to gain multiple perspectives. Overall, 13 different children participated in KidsTeam UW for this case study (Appendix A.1). Adults in the core group consisted of researchers—in computer science, design, and child-computer interaction— alongside undergraduate and graduate students. All adults (including researchers) worked with the children as design partners in close collaboration online. Across these online co-design sessions, we explored designs for and/or with the robot platform with a variety of co-design techniques (Appendix A.2). We used three platforms to facilitate this online collaboration. First, we used Zoom video as both children and adults were familiar with the platform from online schooling during lockdown. Second, we used Google Slides as our main collaboration tool due to its free access for children. Finally, adults used Discord to communicate with each other behind-the-scenes during and between design sessions.

Each of the 20 co-design sessions began with Welcome Time (15 minutes), in which children and adults gathered together to talk and socialize. During this time, we implemented the introductory activity of Question of the Day to prime everyone to think about the session goals. Then, facilitators presented the design prompt for the day. Design prompts were selected to either (1) utilize the robots for a shared design activity or (2) design the robot control platform. During Design Time (45 minutes), designers interacted together in Zoom breakout rooms (2 children, 2 - 3 adults) using PD techniques online [36, 75] to create artifacts, evaluate co-design technologies, and explore activities with the telepresence robots. One or two adults stayed behind as the "eagle eyes" to watch all of the breakout rooms and take care of logistics, such as troubleshooting Internet problems. Finally, in Discussion Time (15 minutes) we gathered everyone together in a single Zoom room to present designs, make final suggestions, reflect on the activity of the day, and propose new activities (e.g., sports, dancing, and drawing) to generate future session ideas.

4 DESIGN CONTEXT: TABLETOP TELEPRESENCE ROBOT SYSTEM DESIGN ITERATIONS

4.1 Physical Setup

During the transition to online during the COVID-19 lockdown, the children in KidsTeam UW used various family-owned devices to attend the sessions. This led to inconsistencies regarding camera quality, screen size, and input capability. Additionally, because some children found it challenging or uncomfortable to use a front-facing camera, they turned videos off; which sometimes resulted in them disengaging entirely from the sessions. So, we redesigned the technology setup using Cooperative Inquiry to help children's engagement and participation in the sessions. As a result of this process, we provided each child a Surface tablet and custom 3D printed stand and flip mirror (Fig. 2a). This setup enabled children to share their workspace over video, while leaving them the option to opt-in to front-facing camera use. Once children were familiar with the tablet and mirrored stand, we introduced Sony Toio robots (two per KidsTeam UW member). The robots support relative and absolute control using techniques similar to Anoto pen—when used with a provided play mat—and encourage low tech modifications with their blank-slate design. Robots are connected via Web Bluetooth to a web-based control interface (Fig. 2b). Children can control their robots locally or connect to remote robots via a WebSocket. The on-screen controls allow children to move the robots using an on-screen joystick, on-screen absolute position control, and expression buttons (spin, shuffle, party). Or, children can enable a mirrored connection, where the remote Toio replicates the absolute position detected from the local Toio.

4.2 Software

We used a web platform to enable adults and children to design the on-screen robot control interface, and see those designs reflected through regular updates to the application. The design of the UI took place over three phases. Throughout this three-phase design process, we integrated children's feedback which we collected through dialogue, sketches, and observation. In the first phase (sessions 1 - 7), we introduced the robots to children with a relative control system to move local and remote robots. During this phase, we started with directional buttons only (front, right, back, left), and asked children to provide design ideas for the control interface. As a result of children's design ideas and sketches, we added a joystick

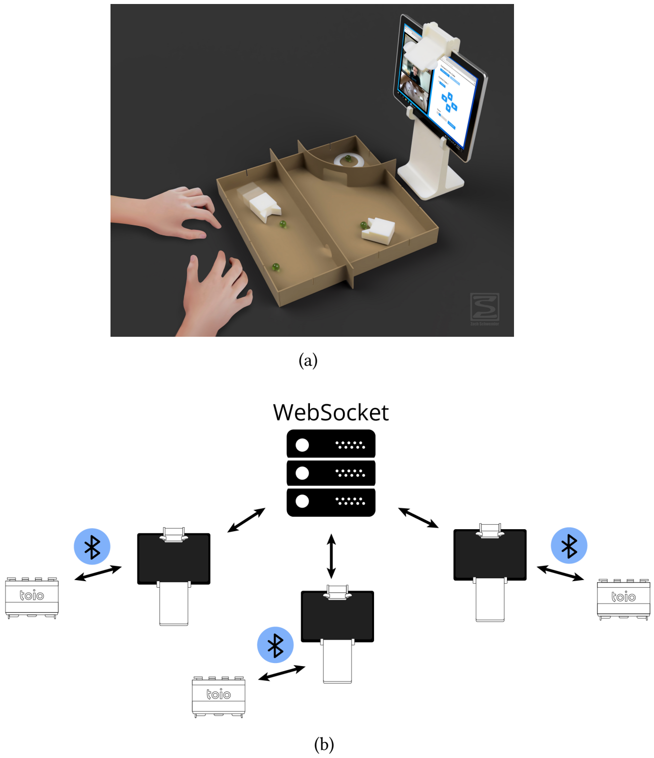


Figure 2: (a) Tablet computer with mirror, stand, tabletop play area (b) Schematic of Telepresence Robot Connection

and speed control to enable finer robot movement. Moreover, children proposed adding buttons with pre-programmed movements that they could use for expressions, in response we introduced spin, party, and shuffle buttons to the app. Our objective in phase one was to familiarize children with tele-operation of the robots and refine the relative robot control interface. In the second phase (sessions 8 - 15), we added the use of absolute position control to the system. In phase two, our objective was to explore the impact of absolute position control on children's tele-operation of the robots, and work with them to refine the absolute control interface. The absolute control scheme enabled users to click on a location on the screen to move the robot to a corresponding position on the play mat. In this phase, we also introduced the mirrored control, where a remote robot replicates the position of a local robot. Children reported liking that they could see the position of the remote robot via the UI, which they used to supplement their knowledge of the robot position from Zoom video. During this phase, children also reported that managing two windows for Zoom video calls and robot control was challenging. As a result, we co-designed an integrated video layout in session 15. During the third and final phase (sessions 15 - 20), we implemented the suggestions from the previous sessions to create a controller with an integrated video conferencing system. Thereby eliminating the need for children to switch between the control application and Zoom. We also added notifications for remote control events based on children's concerns about the accountability of remote operators. During remote control, the application indicates the remote user name and their actions to the robot owner. The resulting system incorporates children's preferences and design ideas to produce a tabletop robot tele-operation interface for online co-design with children.

5 DATA COLLECTION AND ANALYSIS

Video data: We used Zoom video chat to record video and audio data from the main room and breakout rooms from each session. In total, we collected 100+ hours of video across the 20 sessions. Transcripts from the sessions were auto-generated from Zoom, we then reviewed these transcripts for accuracy and fixed any transcription errors.

Artifacts: We used Google Slides to collect artifacts from the children. Such artifacts included hand-drawn or digitally created prototypes produced during co-design sessions, children's perspectives on proposed interface designs and prototypes, and digital notes from the adults. To capture documentation of children's physical designs, adults asked children to hold up their designs on video so they could capture screenshots of the artifacts to add to Google Slides.

Data Analysis: To understand our long-term online co-design process, we started with an open inductive analytical process and grounded methods [11]. We created analytic memos to analyze the videos in Spring 2022 [59]. Primary and secondary reviewers began by watching all of the videos. Initially, primary reviewers wrote up memos about the interactions in 10 minute segments. After the primary reviewers finished the first round of memoing [59], a secondary reviewer watched the videos and reviewed the primary reviewer's initial memo. The secondary reviewer added any missing interactions and additional information to the memos. We asked both primary and secondary reviewers to note any interactions they thought were pertinent to our analysis, such as what kinds of collaborations occurred, what kinds of designs were created, and how children and adults interacted online.

After we generated memos for the 20 co-design sessions, we open coded them in Spring 2022. We began with codes such as sibling dynamics, difficulties with Internet and Bluetooth connections, challenges with robots, future design ideas for the robots, the use of physical materials in online co-design, any novelty effect, practice effect, and/or fatigue in co-designing with the robots, and troubleshooting online in co-design. For the coding process, we relied on the same primary and secondary analytic memo writers. Primary coders started coding with the initial codebook and justified each code. Throughout the process, coders were given the chance to add, delete, and edit the initial codebook. After the primary coders completed the first round of coding, secondary coders reviewed primary codes. Through consensus coding [42], secondary coders put +1 for agreements or -1 for disagreements, explaining their reasonings. Disagreements about coding were resolved by the research group through interrater consensus [42]. Instead of quantitative counts, we chose to do consensus coding to negotiate and consider the richness of the qualitative data collaboratively [28].

Our open coding and consensus coding spanned 10 group meetings from Spring to Summer 2022. Through axial coding and thematic generation [11], we created two main coding categories in our codebook: (1) **Co-design processes** (collaboration: child-to-child, adult-to-child, adult-to-adult, siblings at home); communication (feedback, satisfaction, frustration); troubleshooting (infrastructure, robot design) and iteration; and (2) **Technology innovation** (technology maintenance, exploration of 2-D, 3-D spaces, frustration with Toio, satisfaction with Toio, collaboration opportunities with Toio). We coded all the session transcripts with iterative discussions and updates to the codebook, while identifying key themes that emerged during this process. Finally, we selected example vignettes as a way to demonstrate snapshots of the participants' characters, experiences, and composites to convey the particular purpose of the themes [65].

6 FINDINGS

In this section, we present three themes that emerged from the interplay of long-term online co-design processes and the tabletop telepresence system we designed. When discussing the findings, we refer to mixed groups of adults and children as "co-designers".

6.1 Theme 1: The Technology Space Over Time

For Theme 1, we describe the impact of the technology space on long-term online co-design: the challenges that arose from children's role as technology managers, and how they were notable and consistent parts of the process, even as children became proficient with the technologies used during our longitudinal co-design engagement. Then, we address the expanded technology space with the addition of the telepresence robots and its impact on children's experiences of physical prototyping online.

6.1.1 Online co-design processes: Navigating unexpected technical issues over time. Constructing the online co-design technology space (e.g., the Zoom "room", robots, Google Slides) relied on the technical knowledge, collaboration, and commitment of both children and adults. Despite our efforts to ensure the consistency of the co-design technology space by providing tablets and telepresence robots, and using a standardized Zoom configuration, technical troubleshooting remained a significant hurdle in online sessions. Notably, these issues sprang out of children's varied and morphing use of the provided tablets (Vignette 1). Such variability meant that both troubleshooting efforts and design considerations for the telepresence robot control application needed to account for children's individual setup. As a result of these varied setups, troubleshooting required significant efforts from adults and children. Vignette 2 presents a sample interaction between Katelyn, Desirae, and Isaac where they used an unexpected approach, showing a reflection of their screen with the provided flip mirror, to share the configuration of their Zoom window and robot control application.

> **Example Vignette 1.** During early sessions, children consistently used standardized Surface tablet devices without issues. However, some children became reluctant to use these devices over time, even when specifically prompted to. Or, in the case that a child made use of the provided tablets throughout the study, they customized the device configuration and used the provided devices in unexpected ways. For example, Desirae and Katelyn utilized the screen tiling settings to display both the Zoom call and robot controls simultaneously on the tablet. Andreas switched between Zoom and the online robot control application, as he found tiling windows on the provided tablets confusing. Avery used the tablet for robot control but joined Zoom from a separate device.

> **Example Vignette 2.** When Isaac asked Desirae about her screen configuration during session 7, she used her flip mirror to show a reflection of the screen (Fig. 3a). She used this work-around since she could not use screen share on Zoom to show the Zoom window. When Desirae initially showed Isaac her screen, she had configured the Zoom window as an overlay on the robot controls. When asked about whether she used this setup when controlling Isaac's robots remotely, Desirae responded by showing a tiled view (Zoom on the left, and the robot control application on the right). The group went on to discuss the benefits and downsides of each screen configuration, with Desirae providing feedback about how the web app could be improved to be more useful to her in the tiled view.

6.1.2 Design innovation: Tangible collaboration in online co-design. The longitudinal aspect of the project presented an opportunity to habituate children to technology designs that would be unwieldy for them to use in a short-term study. In the beginning, children and adults were overwhelmed by the multi-level technical setup. As children's confidence managing the technology increased over time, we started using the robots as part of physical design activities. This change extended the technology space of online co-design from visual to tangible, which changed the character of physical design collaborations. Prior to the addition of the robots, children—who were asked to create physical prototypes with craft materials during online sessions—were primarily focused on their own designs, working in parallel with little cross-collaboration. In contrast, when children used the robots during physical prototyping, they spent significant time discussing and responding to peer's design ideas, and held a sense of ownership in the designs they contributed to remotely (Vignette 3). Meanwhile, since tele-operation of the robots required a video stream, we found that children were more likely to leave their video on during sessions involving the robots, resulting in their designs being more frequently visible to remote collaborators. This increased visibility provided adults with more opportunities to comment and ask questions about children's motivations and design process.

> **Example Vignette 3.** In session 4, we asked participants to design a maze for the robots to move marbles to a target location. During this process, Sonja and Harper provided feedback about the design of the stage Andrea had built. This feedback emerged from their use of the tele-operated robot to play with the marble maze in Andrea's space. In response, the group discussed ways to make the maze easier, and ways to make the robots more effective at moving marbles.

This vignette illustrates the interconnectedness of our project's focus on designing the tangible online co-design space (through modifications to the robots and the way they are controlled), while also utilizing our technology as a tool for remote physical prototyping.

Sonja: [tele-operating Andrea's robot] "Why are all the marbles in the corner, that makes it hard!"
Andrea: "Do you think any attachments to the robot would be helpful right now?"
Harper: "Maybe like a scoop thingy, a shovel?"

6.2 Theme 2: Social Landscape of Long-Term Online Co-Design

While in-person co-design is typically hosted in a single location, online co-design sessions are distributed by nature, and expand the design space to include individual's settings [22]. During our project, we observed that children primarily joined KidsTeam UW from their home. This setting impacted the social aspects of online co-design, changing children's engagement in the session and the way bonds were built between co-designers. Meanwhile, the telepresence robots also improved the social characteristics of online co-design, inviting co-designers connect in new ways as a result of their physical presence in the home.

6.2.1 Online co-design processes: Home context over time. The home context played two roles in the social aspects of online co-design: distraction and inspiration. For distraction, children were subjected to factors at home outside of the design session, competing for their attention [22]. In several sessions, Avery opted to prepare food in her kitchen instead of engaging in the activities. And Brooklynn, who reported preferring online to in-person co-design, frequently stepped away during sessions. In these moments of distraction, adults tried to regain children's focus, asking probing questions about the design prompt or questioning whether the children were still available. However, children had varied or sometimes no responses to these questions. In a sense, the forward progression of the online co-design sessions was heavily dictated by children's home environment, and was sometimes outside of the adults' influence.

On the other hand, the inclusion of children's home environments in the social landscape of online co-design consistently offered unique opportunities for co-designers to find inspiration. For example, co-designers frequently discussed their home setting, which allowed them to learn about each other's home life over time. This led to children's designs relating to their home lives (Vignette 4). With adults sometimes even prompting design ideas by asking children to consider the pets, rooms, or families that they had shared in previous sessions (Vignette 5).

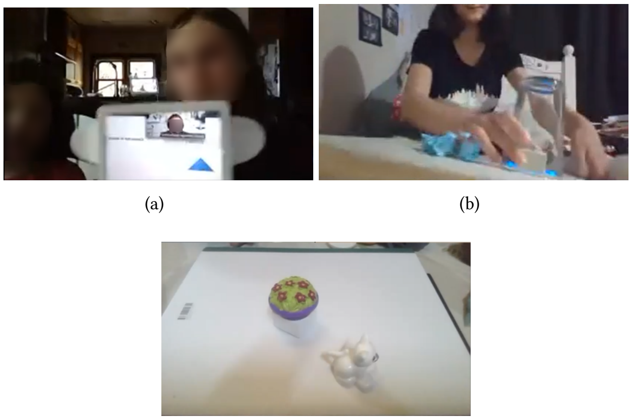
Example Vignette 4. From the beginning of the project, Brooklynn consistently worked next to her 3-year-old sister during online co-design sessions, resulting in facilitators and other children making a connection with Brooklynn's sister. In session 13, when asked about what buttons she would add to the robot interface, Brooklynn proposed creating a way for the robot to monitor her sister, who could not go to sleep. She proposed a robot that turns into a walkie-talkie that would sing lullabies to her sister, allow her to watch her sister sleeping, and alert her when her sister woke up.

Example Vignette 5. Sonja and Avery adopted a puppy at the beginning of the project. The puppy was frequently shown on video during co-design sessions. In session 7, to inspire new ideas when the conversation about designing controllers for the robots had gotten stale, Logan reminded Avery about the family dog she introduced previously, and asked whether they could design a controller for canines. To achieve this, the group adapted one of the dog's toys into a way to move the robot, proposing a steering wheel that would be able to control the telepresence robots to gather all the dog's toys.

6.2.2 Design Innovation: Enabling new connections and play with physical telepresence. We found that the telepresence robots expanded online co-designer's interactions with each other in their home context in a tangible and playful way. In conventional online co-design where one person talks at once, while others remain silent to prevent cross talk, the robots' physicality provided an additional interaction channel besides the video call for children. When the robots were added, we found children consistently used them to engage with others in silly ways (Vignette 6). Also, because the addition of the robots allowed co-designers to interact with each-other's spaces directly, both adults and children naturally incorporated artifacts from their home on-the-fly when playing with them (Vignette 7). This physicality and incorporation of co-designer's personal belongings and home spaces sparked conversations around their personalities and preferences, and increased the groups' sense of connection compared to sessions without the robots.

Example Vignette 6. In session 1, after learning about robot's telepresence functionality, Andreas specifically requested to connect to the robots on the facilitator's desk, exclaiming "I want to connect to your robots!" In spite of the robots not being visible on camera (only audio of the robots moving is heard through the video call), Andreas enjoyed being able to playfully move the facilitator's robots. Once connected, Andreas joked about his use of the robots, "I must connect, I will destroy you!"

Example Vignette 7. Co-designers commonly incorporated personal items when using the robots (Fig. 3c). In session 8, Tyler (adult) added knick-knacks to her play mat and encouraged Sonja, Theo, and Avery to try to moving them with the robots in order to practice a new control scheme. The group cooperated to push heavier items and even discussed the origin of the more interesting artifacts. In session 1, Sonja covered her robot with a cup when she became frustrated with the other children who were tele-operating her robot (Fig. 3b). As a result of this action, the co-designers in this breakout group discussed the potential discomfort of allowing a tele-operated robot into their



(a) (b) (c)

Figure 3: (a) Desirae shows her screen with the flip mirror (b) Sonja traps her robot with a cup (c) Isaac puts a toy on the robot

personal space and whether the remote control of robots should require permission from robot owners.

6.3 Theme 3: Flexibility as a Technique for Long-Term Online Co-Design

In online settings, children have different physical spaces, technology setups, and design materials, which requires co-designers' to be adaptable in response to such variability and unpredictability [36]. Early in our project, this unpredictability created gridlock when children were unprepared for the planned design activity. However, we found that co-designers were more successful and effective when they had autonomy over their co-design process, including how they chose to utilize the robot, instead of following a prescribed approach in response to the design prompt.

6.3.1 Online co-design processes: Adaptation in online co-design with flexible methods. Online co-design comes with variability and unpredictability [36]. We often observed children joining the session from different places (e.g., a moving car, or their bed) and devices (e.g., mobile phones) that limited their engagement in on-screen prototyping, craft activities or telepresence robot use. Facing such uncertainties challenged the planned activities, commonly resulting in bottlenecks and frustration among co-designers (Vignette 8).

To cope, we progressively allowed co-designers more autonomy in selecting co-design techniques, rather than prescribing a specific approach. Leveraging their accumulated and diverse experiences with design tools over the course of the project, co-designers were able to adapt strategies that worked best in their variable contexts. With such methodological flexibility, co-designers moved through design prompts more effectively, preventing lost time as a result of adults and children trying to work with a co-design technique that was mismatched with children's capabilities. This strategy also re-centered children's role from technical troubleshooters back to designers, allowing them to engage in sessions even if their technology was not working as expected. While this deconstruction of design sessions posed the risk of unwieldy complexity and unfocused outcomes, it resulted in co-designers spending more time designing and less time feeling frustrated as a result of technical issues or missing materials (Vignette 9).

> **Example Vignette 8.** In session 5, we asked groups to design and test a robot attachment prototype that could hold a pen to enable drawing using craft materials. However, this task required children to have (1) a charged robot, (2) suitable prototyping materials, (3) access to the web application, (4) a successful Bluetooth link between the app and the robot, and (5) a functional pen attachment prototype. Due to such complexity, teams spent the majority of the session troubleshooting their technology and trying to get a pen to attach to the robots, rather than co-designing. When children shared their experience of this session, Avery said that she did not understand the purpose of the activity, Andreas gave a thumbs down, and Cal said he hated spending the session troubleshooting the system.

> **Example Vignette 9.** In session 10, we asked children to brainstorm emotions that the robots could express without specifying the teams' choice of design approach to complete this task. As a result, some children controlled robots via the on-screen interface, some puppeteered them with their hands, some moved their bodies to demonstrate the emotion, some participated in verbal discussion, and some created a collage of pictures depicting the intended emotions in Google Slides. Instead of getting stuck on meeting the requirements to complete a specified design method, groups were able to adapt to their team's preparation, environment, and preferences. As a result, we collected a wide variety of design ideas about emotional expression with the robots during this session.

6.3.2 Design innovation: Telepresence robots as a flexible, shared point of interest. Over time, the robots emerged as a flexible tool, with co-designers opting to adapt their use of them to suit their personal preferences and the design prompt. Over the study, we asked children to design stages, costumes, stories, movements, games, and attachments for the robots. With time, children developed preferences about which of these techniques they preferred. When our facilitation strategy of co-design sessions became more flexible about the co-design technique applied, children also gravitated toward a more varied use of the robots (Vignette 9). In addition, because all children had identical robots, and robots were a central tool in the sessions, they emerged shared point of focus. This shared focus on the robots along with their telepresence functionality resulted in co-design groups creating unique designs. In one case, imagining how a story could be told across multiple locations (Vignette 10). In another, utilizing the unexpected movement of the robot as inspiration for new features of the robot control interface (Vignette 11).

Example Vignette 10. In session 14, we asked children to create stories with the telepresence robots. One group explored how the "stage" of the robots could extend across multiple children's homes. In their story a child (represented by a robot) falls through an interdimensional portal in Raj's house. Raj explained, "So here's Michael, and then he sees this portal. Then he touches it. Then he accidentally slipped and fell. And then he disappeared and he was gone." The group discussed where the robot went, and proposed that it might have "teleported" to Theo's home. In this way, Raj and Theo's narrative was continuous even though the two children were not co-located because of the connection through their use of a shared physical artifact (the Toio robot).

Example Vignette 11. During session 13, Isaac's robot was continuously moving off of the stage because of an unknown participant acting as a rogue robot operator. Due to this unexpected movement, Sonja and Katelyn could not control the robot predictably. Thus, Isaac was continuously redirecting the robot with his hands to avoid the table edge. In response to such unexpected robot behavior, the co-designers discussed what emotion the robot might be expressing, comparing it to a lemming and suggesting that this behavior might be used in a "self-destruct" button or a "run-away" button. From here, the breakout group discussed what the robot might be running away from, imagining how it might be the result of an unwanted display of affection or a threat, subsequently designing these expressions for the robot too.

7 DISCUSSION

As a result of this longitudinal case study and design narrative we present three contributions for understanding co-design with children: (1) insights about the future of online co-design that emerged from our in-depth look at process and design; (2) a conceptual model for longitudinal co-design online; and (3) opportunities for further research on longitudinal co-design online, including the generation of new PD methods, techniques, and theories.

7.1 Lessons learned: The possibilities of online co-design

Prior research on co-design online with children notes that sessions and designers will encounter many technical issues within online co-design [36]. Even after 20 sessions on the same iterative and evolving designs, we still observed children encountering challenges in utilizing both enterprise collaboration software (e.g., difficulties screen sharing over Zoom, how to present in Google Slides), and our own online robot control system. In Theme 1, these technical issues taught us about how a lack of physical co-presence — which allows adults to help troubleshoot and work through technical issues directly — resulted in significant, recurring technical difficulties in online co-design. As we made modifications to the technical space of online co-design, with the addition of the tabletop telepresence robots, we observed an increased sense of collaboration and ownership of physical projects in distributed design teams. Through embodied interaction, people develop spatial and physical metaphors as they relate to understanding new concepts [33], gestures to coordinate and share meaning [25], and encoding of memory in perceptual and sensorimotor systems [6]. Historically, embodied aspects of co-design, like crafting and play acting have played an important role in creativity and collaboration [54]. However, online co-designers in traditional configurations are unable to engage with each other's crafts or respond to each other's movements. Through the tabletop telepresence robots, children were engaging in physical collaborations, providing feedback on each other's physical prototypes, and feeling a shared sense of ownership over projects. We argue that this preliminary finding demonstrates a need for child-computer interaction researchers to continue to consider physicality in fully remote co-design settings [52].

Online co-design is not just about working with children in isolation, but working with their multiple contexts [22]. This distributed nature means that in online co-design there is no separation between home and design contexts, they are one in the same. In Theme 2, we discussed how the social context of the home both inspired and distracted children in co-design. We found that the home context played an important role in the relationships between co-designers online, providing opportunities to make connections through sharing of personal belongings, family, and pets. Over time, co-design teams also began utilizing these connections as jumping off points in their iterative design ideations. The same inspiring home contexts competed for children's attention during the session, resulting in unexpected distractions. The addition of the telepresence robots provided a new way for designers to connect and play together in their homes. While we were each physically stuck in isolation, the telepresence robots were distributed across our settings, making them the single common connection between designers' spaces. Resnick [58] considered the idea of "distributed constructionism"; that is, how technological networks could help children discuss, share, and collaborate on constructions remotely. Similarly, Zaphiris et al. [84] extended the notion of distributed constructionism to PD, bringing forth that co-design methodology needs ways for children to connect and collaborate when engaged virtually. Through this longer-term deployment of telepresence robots that help children engage in distributed constructionism [58], we discovered the home environment combined with our telepresence robots created a new way to understand distributed constructionism. We believe that child-computer interaction researchers can consider how tools and processes can integrate children's home setting into the the discussion, sharing, and collaboration on constructions online.

Finally, Theme 3 examined the need to offer flexibility in online co-design in longer term projects. Though we tried to standardize the co-design of our telepresence system with the same specific craft materials, tablets and settings, robots, and design strategies, we encountered more variability than similarities as a result of children's high level of autonomy in online co-design. Instead, online co-design functions best when teams are open to improvisation and constantly vigilant to adaptation [36]. Across our project, prescribed co-design techniques became unsustainable. In response, we moved toward supporting improvisation on a structural level, encouraging co-designers to explore what techniques worked for them, prioritizing the design goal in sessions rather than the design method that children should use for their designs. Working with the telepresence robots over time and developing a shared understanding of them allowed these tangible objects to act as anchor points for the design teams. Children were able to control the same robots together across different spaces and time zones synchronously, or they were able to design for their own robots and compare their experiences with this shared artifact. The robots were able to function in a variety of ways, which we leveraged to account for variability and differences across spaces. Intersubjectivity is the idea of constructing new understandings within a social environment through the combination of different perspectives of social members and interlocutors. Having intersubjectivity contributes to the success of online collaborations [40]. We believe that co-design methods suitable for online engagements require in-depth flexible considerations in helping children share the same experiences together synchronously. Specifically, use of the Toio robots in co-design allowed children to share the same experience (e.g., creating and using the maze together, designing a sport for the robots) while being far apart. In our case, we emphasized the use of physicality in telepresence to enhance children's sense of shared experience. Future co-design work needs to consider how online tools can enable designers to be flexible to accommodate variability in online co-design processes while supporting shared intersubjectivity among children with physical interactions in mind.

7.2 A conceptual model of online co-design over time

COVID-19 forced the entire world of children and adults into quarantine for two years, from 2020 - 2022 (with some parts of the world still in restrictions at the time of this writing). Prior work on children's co-design has mostly focused on either the co-design of longer-term projects in-person [66] or online co-design that is fragmented across multiple projects [22, 36]. In the analysis of more fragmented projects online, we note that the researchers' assumption is that of co-design process as influencing and shaping the design product and artifacts (Fig. 4). Design techniques like Bags of Stuff [75], Would You Rather [63], and Comicboarding [47] are used to "enable children and adults to work together to create innovative technology for children" [27]. In contrast, our design case study examines the longitudinal online co-design of a single iteratively designed project (tabletop telepresence robots) over the course of two years. As we engaged in the design of a tool to bring physical telepresence to online interaction, we observed that the design of our technology platform also shaped our online co-design processes (e.g., considerations of physicality online, connecting children through shared play online, and a need for planned flexibility online). We argue that it is mainly through the longitudinal process of this design over time on a single project, that we were able to notice how the design itself started to shape our own co-design processes (Fig. 4).

Through this work, we call on aspects of Schön [60] that as designers construct design worlds and the dimensions of the problem space, the designer also invents the moves needed to attempt to find solutions. Schön calls this process "see, draw, see" [60]. As

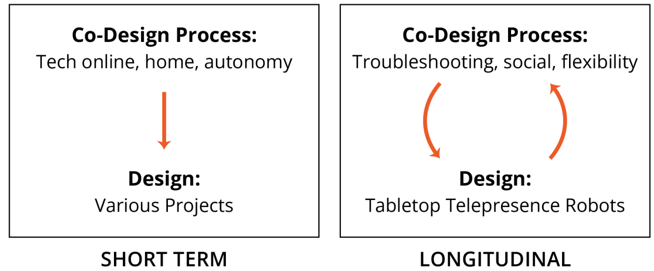


Figure 4: A conceptual model showing the relationship between the short term (left) and longitudinal (right) online co-design process and the product of design.

designers, we first "see" the materials and what is possible, then "draw" in relation to that representation of the materials. For us, we limited our "draw" interaction to a specific medium (the telepresence robots) and process (online co-design). Because of our specific engagement with the medium, we are able appreciate the materials for what they are (the physicality, playfulness, and sharedness of telepresence robots), and thus can "see" (again) how this specific longitudinal engagement shaped our online co-design processes.

7.3 The need for future longitudinal research for online co-design

While online co-design comes with challenges, it serves an important function in the co-design toolkit, enabling children to participate even when they would not ordinarily be able to do so as a result of factors like geography, weather, transportation, illness, or disability [5, 71]. As a result, online co-design can provide broader access for a diversity of participants [5, 22, 36]. Therefore, we need to consider the unique aspects of online co-design for longer term projects, and the facilitation strategies and technologies that might strengthen this approach. Previously, insights from in-person long term co-design projects have shaped the methods, techniques, and theories of co-design. For instance, the long term co-design of the *International Digital Children's Library* in the late 1990s and 2000s supported Druin's work to create Cooperative Inquiry as a philosophy, method, and collection of techniques for PD [19, 20]. On a broader scale, the long term PD of the public library *Dokk1* created new techniques and technologies to scaffold the involvement of the general public in designing community resources [14, 15].

Our design project is an extension of the traditional ways in which PD and child co-design processes are ultimately shaped by the product we create. From the difficult situation of COVID-19 and associated lockdowns, an opportunity emerged to move PD online at a larger scale. Therefore, we focused on a product (tabletop telepresence robots) to both design new ideas around telepresence for children, and explore how this added physical telepresence shapes online co-design processes. While COVID-19 infection rates have improved, and lockdown restrictions have eased, there is still a need to consider distributed online co-design, not just as a backup solution for emergencies and disasters, but a true design methodology of its own. We argue that our insights emerged from a "critical mass" of time, number of participants, and scale of design which resulted in a chain reaction of insights about online co-design. These insights teach us that there is an opportunity for new techniques and methods in this emerging space for co-design.

8 CONCLUSION

Our longitudinal study (2 years, 20 sessions) examined the online co-design process through the design of a tabletop telepresence robot platform with 13 children (ages 8-12) at the KidsTeam UW intergenerational PD teams. Our findings provide insights into the long-term co-design process and the strategies developed to adapt co-design methods to previously identified opportunities and challenges of online co-design [22, 36]. Through our analysis of a longitudinal co-design study, we present deeper insights into online co-design, specifically the opportunities and challenges that emerged during long-term online co-design with children. In addition, we described a conceptual model around long term co-design online, which identifies that the process of online co-design and the product of online co-design design shape one another. We showed how the online technology space demanded children to attend to and manage troubleshooting, how the home setting provided social context that impacted dynamics in online co-design, and how supporting children's autonomy by allowing them to select co-design techniques lead to more efficient design outcomes online. As more researchers and designers consider online co-design for longitudinal work, we identify the need for more longitudinal online co-design research to generate new methods, techniques, and theories for this latent co-design methodology.

9 SELECTION AND PARTICIPATION OF CHILDREN

Recruitment for KidsTeam UW children involved word-of-mouth, print media, and emails. Children ages 8 - 12 are able to participate. Parents and guardians of child participants signed a consent form, along with child assent. We informed both families about the goals of the study, risks in safety and privacy, and confidentiality protocols. During the consent process, we indicated to families that children and parents were free to withdraw at any time. Researchers acted as facilitators online and made sure children did not feel under any pressure to participate with the study activities. All research has been approved by our university's Institutional Review Board. All adult facilitators go through ethics and safety training for children at our institution. All children's data were anonymized for the analysis and stored on a secure server.

ACKNOWLEDGMENTS

This material is based upon work supported by the Jacobs Foundation Research Fellowship Program. We would like to thank Sony for supporting the project with Toio robots. We would also like to thank the children and student volunteers at KidsTeam UW for their contributions.

REFERENCES

[1] June Ahn, Tamara Clegg, Jason Yip, Elizabeth Bonsignore, Daniel Pauw, Lautaro Cabrera, Kenna Hernly, Caroline Pitt, Kelly Mills, Arturo Salazar, et al. 2018. Science everywhere: Designing public, tangible displays to connect youth learning across settings. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–12.

[2] June Ahn, Tamara Clegg, Jason Yip, Elizabeth Bonsignore, Daniel Pauw, Michael Gubbels, Charley Lewittes, and Emily Rhodes. 2016. Seeing the unseen learner: designing and using social media to recognize children's science dispositions in action. *Learning, Media and Technology* 41, 2 (2016), 252–282.

[3] Dima Albadra, Zeinab Elamin, Kemi Adeyeye, Eleni Polychronaki, DA Coley, J Holley, and Alexander Copping. 2021. Participatory design in refugee camps: comparison of different methods and visualization tools. *Building Research & Information* 49, 2 (2021), 248–264.

[4] Luis Almeida, Paulo Menezes, and Jorge Dias. 2022. Telepresence Social Robotics towards Co-Presence: A Review. *Applied Sciences* 12, 11 (2022). https://doi.org/10.3390/app12115557

[5] Maryam Bandukda, Giulia Barbareschi, Aneesha Singh, Dhruv Jain, Maitraye Das, Tamanna Motahar, Jason Wiese, Lynn Cockburn, Amit Prakash, David Frohlich, et al. 2022. A Workshop on Disability Inclusive Remote Co-Design. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–5.

[6] Lawrence W Barsalou. 1999. Perceptions of perceptual symbols. *Behavioral and brain sciences* 22, 4 (1999), 637–660.

[7] Arpita Bhattacharya, Calvin Liang, Emily Y Zeng, Kanishk Shukla, Miguel ER Wong, Sean A Munson, and Julie A Kientz. 2019. Engaging teenagers in asynchronous online groups to design for stress management. In *Proceedings of the 18th ACM International Conference on Interaction Design and Children*. 26–37.

[8] Sara A. Bly, Steve R. Harrison, and Susan Irwin. 1993. Media Spaces: Bringing People Together in a Video, Audio, and Computing Environment. *Commun. ACM* 36, 1 (jan 1993), 28–46. https://doi.org/10.1145/151233.151235

[9] Scott Brave, Hiroshi Ishii, and Andrew Dahley. 1998. Tangible Interfaces for Remote Collaboration and Communication. In *Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work* (Seattle, Washington, USA) *(CSCW '98)*. Association for Computing Machinery, New York, NY, USA, 169–178. https://doi.org/10.1145/289444.289491

[10] Elizabeth Cha, Samantha Chen, and Maja J Mataric. 2017. Designing telepresence robots for K-12 education. In *2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. 683–688. https://doi.org/10.1109/ROMAN.2017.8172377

[11] Kathy Charmaz. 2016. Shifting the grounds: Constructivist grounded theory methods. In *Developing grounded theory*. Routledge, 127–193.

[12] Tamara Clegg, Jason C Yip, June Ahn, Elizabeth Bonsignore, Michael Gubbels, Becky Lewittes, and Emily Rhodes. 2013. When face-to-face fails: Opportunities for social media to foster collaborative learning. (2013).

[13] Bronwyn Cumbo and Neil Selwyn. 2022. Using participatory design approaches in educational research. *International Journal of Research & Method in Education* 45, 1 (2022), 60–72.

[14] Peter Dalsgaard. 2012. Participatory design in large-scale public projects: Challenges and opportunities. *Design Issues* 28, 3 (2012), 34–47.

[15] Peter Dalsgaard and Eva Eriksson. 2013. Large-scale participation: a case study of a participatory approach to developing a new public library. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 399–408.

[16] Betsy DiSalvo and Carl DiSalvo. 2014. Designing for democracy in education: Participatory design and the learning sciences. Boulder, CO: International Society of the Learning Sciences.

[17] Betsy DiSalvo, Jason Yip, Elizabeth Bonsignore, and DiSalvo Carl. 2017. Participatory design for learning. In *Participatory design for learning*. Routledge, 3–6.

[18] Carl DiSalvo, Illah Nourbakhsh, David Holstius, Ayça Akin, and Marti Louw. 2008. The Neighborhood Networks project: a case study of critical engagement and creative expression through participatory design. In *Proceedings of the tenth anniversary conference on participatory design 2008*. 41–50.

[19] Allison Druin. 1999. Cooperative inquiry: developing new technologies for children with children. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*. 592–599.

[20] Allison Druin. 2002. The role of children in the design of new technology. *Behaviour and information technology* 21, 1 (2002), 1–25.

[21] Allison Druin. 2005. What children can teach us: Developing digital libraries for children with children. *The library quarterly* 75, 1 (2005), 20–41.

[22] Jerry Alan Fails, Dhanush kumar Ratakonda, Nitzan Koren, Salma Elsayed-Ali, Elizabeth Bonsignore, and Jason Yip. 2022. Pushing boundaries of co-design by going online: Lessons learned and reflections from three perspectives. *International Journal of Child-Computer Interaction* 33 (2022), 100476.

[23] Sean Follmer, Hayes Raffle, Janet Go, Rafael Ballagas, and Hiroshi Ishii. 2010. Video Play: Playful Interactions in Video Conferencing for Long-Distance Families with Young Children. In *Proceedings of the 9th International Conference on Interaction Design and Children* (Barcelona, Spain) *(IDC '10)*. Association for Computing Machinery, New York, NY, USA, 49–58. https://doi.org/10.1145/1810543.1810550

[24] Elizabeth Foss, Mona Leigh Guha, Panagis Papadatos, Tamara Clegg, Jason Yip, and Greg Walsh. 2013. Cooperative inquiry extended: Creating technology with middle school students with learning differences. *Journal of Special Education Technology* 28, 3 (2013), 33–46.

[25] Susan Goldin-Meadow, Howard Nusbaum, Spencer D Kelly, and Susan Wagner. 2001. Explaining math: Gesturing lightens the load. *Psychological science* 12, 6 (2001), 516–522.

[26] Markus Gross, Stephan Würmlin, Martin Naef, Edouard Lamboray, Christian Spagno, Andreas Kunz, Esther Koller-Meier, Tomas Svoboda, Luc Van Gool, Silke Lang, Kai Strehlke, Andrew Vande Moere, and Oliver Staadt. 2003. Blue-c: A Spatially Immersive Display and 3D Video Portal for Telepresence. *ACM Trans. Graph.* 22, 3 (jul 2003), 819–827. https://doi.org/10.1145/882262.882350

[27] Mona Leigh Guha, Allison Druin, Gene Chipman, Jerry Alan Fails, Sante Simms, and Allison Farber. 2004. Mixing ideas: a new technique for working with young children as design partners. In *Proceedings of the 2004 conference on Interaction design and children: building a community*. 35–42.

[28] David Hammer and Leema K Berland. 2014. Confusing claims for data: A critique of common practices for presenting qualitative research on learning. *Journal of the Learning Sciences* 23, 1 (2014), 37–46.

[29] Daniel Harley, Stefan Grambart, Rodrigo Skazufka Bergel, and Ali Mazalek. 2022. Together Alone: A Tangible Online Narrative. In *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Daejeon, Republic of Korea) *(TEI '22)*. Association for Computing Machinery, New York, NY, USA, Article 5, 11 pages. https://doi.org/10.1145/3490149.3501311

[30] Seth E. Hunter, Pattie Maes, Anthony Tang, Kori M. Inkpen, and Susan M. Hessey. 2014. WaaZam! Supporting Creative Play at a Distance in Customized Video Environments. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 1197–1206. https://doi.org/10.1145/2556288.2557382

[31] Finn Kensing and Jeanette Blomberg. 1998. Participatory design: Issues and concerns. *Computer supported cooperative work (CSCW)* 7, 3 (1998), 167–185.

[32] Robert E. Kraut, Darren Gergle, and Susan R. Fussell. 2002. The Use of Visual Information in Shared Visual Spaces: Informing the Development of Virtual Co-Presence. In *Proceedings of the 2002 ACM Conference on Computer Supported Cooperative Work* (New Orleans, Louisiana, USA) *(CSCW '02)*. Association for Computing Machinery, New York, NY, USA, 31–40. https://doi.org/10.1145/587078.587084

[33] George Lakoff and Rafael Núñez. 2000. *Where mathematics comes from*. Vol. 6. New York: Basic Books.

[34] Mathieu Le Goc, Allen Zhao, Ye Wang, Griffin Dietz, Rob Semmens, and Sean Follmer. 2020. *Investigating Active Tangibles and Augmented Reality for Creativity Support in Remote Collaboration*. 185–200. https://doi.org/10.1007/978-3-030-28960-7_12

[35] Kung Jin Lee, YooJung Kim, Wendy Roldan, Jin Ha Lee, and Jason C Yip. 2022. Caring for the community: An academically based community service course in LIS. *Journal of Librarianship and Information Science* (2022), 09610006221132276.

[36] Kung Jin Lee, Wendy Roldan, Tian Qi Zhu, Harkiran Kaur Saluja, Sungmin Na, Britnie Chin, Yilin Zeng, Jin Ha Lee, and Jason Yip. 2021. The show must go on: A conceptual model of conducting synchronous participatory design with children online. In *Proceedings of the 2021 CHI conference on human factors in computing systems*. 1–16.

[37] Min Kyung Lee and Leila Takayama. 2011. "Now, i Have a Body": Uses and Social Norms for Mobile Remote Presence in the Workplace. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI '11)*. Association for Computing Machinery, New York, NY, USA, 33–42. https://doi.org/10.1145/1978942.1978950

[38] Daniel Leithinger, Sean Follmer, Alex Olwal, and Hiroshi Ishii. 2014. Physical Telepresence: Shape Capture and Display for Embodied, Computer-Mediated Remote Collaboration. In *Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology* (Honolulu, Hawaii, USA) *(UIST '14)*. Association for Computing Machinery, New York, NY, USA, 461–470. https://doi.org/10.1145/2642918.2647377

[39] Jiannan Li, Maurício Sousa, Chu Li, Jessie Liu, Yan Chen, Ravin Balakrishnan, and Tovi Grossman. 2022. ASTEROIDS: Exploring Swarms of Mini-Telepresence Robots for Physical Skill Demonstration. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 111, 14 pages. https://doi.org/10.1145/3491102.3501927

[40] M Beatrice Ligorio, Donatella Cesareni, and Neil Schwartz. 2008. Collaborative virtual environments as means to increase the level of intersubjectivity in a distributed cognition system. *Journal of Research on Technology in Education* 40, 3 (2008), 339–357.

[41] Haley MacLeod, Ben Jelen, Annu Prabhakar, Lora Oehlberg, Katie A Siek, and Kay Connelly. 2016. Asynchronous remote communities (ARC) for researching distributed populations.. In *PervasiveHealth*. 1–8.

[42] Nora McDonald, Sarita Schoenebeck, and Andrea Forte. 2019. Reliability and inter-rater reliability in qualitative research: Norms and guidelines for CSCW and HCI practice. *Proceedings of the ACM on human-computer interaction* 3, CSCW (2019), 1–23.

[43] Sharan B Merriam and Elizabeth J Tisdell. 2015. *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

[44] Rebecca Michelson, Akeiylah DeWitt, Ria Nagar, Alexis Hiniker, Jason Yip, Sean A Munson, and Julie A Kientz. 2021. Parenting in a Pandemic: Juggling Multiple Roles and Managing Technology Use in Family Life During COVID-19 in the United States. *Proceedings of the ACM on Human-Computer Interaction* 5, CSCW2 (2021), 1–39.

[45] Laura Millen, Sue Cobb, and Harshada Patel. 2011. Participatory design approach with children with autism. (2011).

[46] Kelly Mills, Elizabeth Bonsignore, Tamara Clegg, June Ahn, Jason Yip, Daniel Pauw, Lautaro Cabrera, Kenna Hernly, and Caroline Pitt. 2019. Connecting children's scientific funds of knowledge shared on social media to science concepts. *International journal of child-computer interaction* 21 (2019), 54–64.

[47] Neema Moraveji, Jason Li, Jiarong Ding, Patrick O'Kelley, and Suze Woolf. 2007. Comicboarding: using comics as proxies for participatory design with children. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 1371–1374.

[48] Ken Nakagaki, Joanne Leong, Jordan L. Tappa, João Wilbert, and Hiroshi Ishii. 2020. HERMITS: Dynamically Reconfiguring the Interactivity of Self-Propelled TUIs with Mechanical Shell Add-Ons. In *Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology* (Virtual Event, USA) *(UIST '20)*. Association for Computing Machinery, New York, NY, USA, 882–896. https://doi.org/10.1145/3379337.3415831

[49] Ken Nakagaki, Jordan L Tappa, Yi Zheng, Jack Forman, Joanne Leong, Sven Koenig, and Hiroshi Ishii. 2022. (Dis)Appearables: A Concept and Method for Actuated Tangible UIs to Appear and Disappear Based on Stages. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 506, 13 pages. https://doi.org/10.1145/3491102.3501906

[50] Hideyuki Nakanishi, Kei Kato, and Hiroshi Ishiguro. 2011. Zoom Cameras and Movable Displays Enhance Social Telepresence. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI '11)*. Association for Computing Machinery, New York, NY, USA, 63–72. https://doi.org/10.1145/1978942.1978953

[51] Hideyuki Nakanishi, Kazuaki Tanaka, Ryoji Kato, Xing Geng, and Naomi Yamashita. 2017. Robotic Table and Bench Enhance Mirror Type Social Telepresence. In *Proceedings of the 2017 Conference on Designing Interactive Systems* (Edinburgh, United Kingdom) *(DIS '17)*. Association for Computing Machinery, New York, NY, USA, 779–790. https://doi.org/10.1145/3064663.3064709

[52] David J Nguyen and Jay B Larson. 2015. Don't forget about the body: Exploring the curricular possibilities of embodied pedagogy. *Innovative Higher Education* 40, 4 (2015), 331–344.

[53] Yuya Onishi, Kazuaki Tanaka, and Hideyuki Nakanishi. 2016. Embodiment of Video-Mediated Communication Enhances Social Telepresence. In *Proceedings of the Fourth International Conference on Human Agent Interaction* (Biopolis, Singapore) *(HAI '16)*. Association for Computing Machinery, New York, NY, USA, 171–178. https://doi.org/10.1145/2974804.2974826

[54] Minna Orvokki Nygren, Marije Nouwen, Priscilla Van Even, Sara Price, Bieke Zaman, and Janne Mascha Beuthel. 2021. Developing ideas and methods for supporting whole body interaction in remote Co-design with children. In *Interaction Design and Children*. 675–678.

[55] Irene Rae, Bilge Mutlu, and Leila Takayama. 2014. Bodies in Motion: Mobility, Presence, and Task Awareness in Telepresence. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) *(CHI '14)*. Association for Computing Machinery, New York, NY, USA, 2153–2162. https://doi.org/10.1145/2556288.2557047

[56] Hayes Raffle, Glenda Revelle, Koichi Mori, Rafael Ballagas, Kyle Buza, Hiroshi Horii, Joseph Kaye, Kristin Cook, Natalie Freed, Janet Go, and Mirjana Spasojevic. 2011. Hello, is Grandma There? Let's Read! StoryVisit: Family Video Chat and Connected e-Books. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI '11)*. Association for Computing Machinery, New York, NY, USA, 1195–1204. https://doi.org/10.1145/1978942.1979121

[57] Janet C Read, Daniel Fitton, and Matthew Horton. 2014. Giving ideas an equal chance: inclusion and representation in participatory design with children. In *Proceedings of the 2014 conference on Interaction design and children*. 105–114.

[58] Mitchel Resnicr. 1996. Distributed constructionism. (1996).

[59] Richard Rogers. 2018. Coding and writing analytic memos on qualitative data: A review of Johnny Saldaña's the coding manual for qualitative researchers. *The Qualitative Report* 23, 4 (2018), 889–893.

[60] Donald A Schön. 1992. Designing as reflective conversation with the materials of a design situation. *Knowledge-based systems* 5, 1 (1992), 3–14.

[61] Alexander P. Schouten, Tijs C. Portegies, Iris Withuis, Lotte M. Willemsen, and Komala Mazerant-Dubois. 2022. Robomorphism: Examining the effects of telepresence robots on between-student cooperation. *Computers in Human Behavior* 126 (2022), 106980. https://doi.org/10.1016/j.chb.2021.106980

[62] Dairoku Sekiguchi, Masahiko Inami, and Susumu Tachi. 2001. RobotPHONE: RUI for Interpersonal Communication. In *CHI '01 Extended Abstracts on Human Factors in Computing Systems* (Seattle, Washington) *(CHI EA '01)*. Association for Computing Machinery, New York, NY, USA, 277–278. https://doi.org/10.1145/634067.634231

[63] Lucy Simko, Britnie Chin, Sungmin Na, Harkiran Kaur Saluja, Tian Qi Zhu, Tadayoshi Kohno, Alexis Hiniker, Jason Yip, and Camille Cobb. 2021. Would You Rather: A Focus Group Method for Eliciting and Discussing Formative Design Insights with Children. In *Interaction Design and Children*. 131–146.

[64] Alexa F. Siu, Shenli Yuan, Hieu Pham, Eric Gonzalez, Lawrence H. Kim, Mathieu Le Goc, and Sean Follmer. 2018. *Investigating Tangible Collaboration for Design Towards Augmented Physical Telepresence*. Springer International Publishing, Cham, 131–145. https://doi.org/10.1007/978-3-319-60967-6_7

[65] Nicola J Spalding and Terry Phillips. 2007. Exploring the use of vignettes: From validity to trustworthiness. *Qualitative health research* 17, 7 (2007), 954–962.

[66] Gerry Stahl. 2016. From intersubjectivity to group cognition. *Computer Supported Cooperative Work (CSCW)* 25, 4 (2016), 355–384.

[67] Ryo Suzuki, Eyal Ofek, Mike Sinclair, Daniel Leithinger, and Mar Gonzalez-Franco. 2021. HapticBots: Distributed Encountered-Type Haptics for VR with Multiple Shape-Changing Mobile Robots. In *The 34th Annual ACM Symposium on User Interface Software and Technology* (Virtual Event, USA) *(UIST '21)*. Association for Computing Machinery, New York, NY, USA, 1269–1281. https://doi.org/10.1145/3472749.3474821

[68] Nathan Tsoi, Joe Connolly, Emmanuel Adéníran, Amanda Hansen, Kaitlynn Taylor Pineda, Timothy Adamson, Sydney Thompson, Rebecca Ramnauth, Marynel Vázquez, and Brian Scassellati. 2021. Challenges Deploying Robots During a Pandemic: An Effort to Fight Social Isolation Among Children. In *Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction* (Boulder, CO, USA) *(HRI '21)*. Association for Computing Machinery, New York, NY, USA, 234–242. https://doi.org/10.1145/3434073.3444665

[69] Katherine M. Tsui and Holly A. Yanco. 2013. Design Challenges and Guidelines for Social Interaction Using Mobile Telepresence Robots. *Reviews of Human Factors and Ergonomics* 9, 1 (2013), 227–301. https://doi.org/10.1177/1557234X13502462 arXiv:https://doi.org/10.1177/1557234X13502462

[70] Aleksandar Velinov, Saso Koceski, and Natasa Koceska. 2021. Review of the Usage of Telepresence Robots in Education. (07 2021).

[71] Greg Walsh, Craig Donahue, and Zachary Pease. 2016. Inclusive co-design within a three-dimensional game environment. In *Proceedings of the the 15th international conference on interaction design and children*. 1–10.

[72] Greg Walsh, Craig Donahue, and Emily E Rhodes. 2015. KidCraft: Co-design within a game environment. In *Proceedings of the 33rd annual ACM conference extended abstracts on human factors in computing systems*. 1205–1210.

[73] Greg Walsh, Allison Druin, Mona Leigh Guha, Elizabeth Bonsignore, Elizabeth Foss, Jason C Yip, Evan Golub, Tamara Clegg, Quincy Brown, Robin Brewer, et al. 2012. DisCo: a co-design online tool for asynchronous distributed child and adult design partners. In *Proceedings of the 11th International Conference on Interaction Design and Children*. 11–19.

[74] Greg Walsh and Elizabeth Foss. 2015. A case for intergenerational distributed co-design: the online kidsteam example. In *Proceedings of the 14th international conference on interaction design and children*. 99–108.

[75] Greg Walsh, Elizabeth Foss, Jason Yip, and Allison Druin. 2013. FACIT PD: a framework for analysis and creation of intergenerational techniques for participatory design. In *proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2893–2902.

[76] Jillian L Warren, Alissa N Antle, Alexandra Kitson, and Alireza Davoodi. 2022. Lessons Learned and Future Considerations for Designing Remotely Facilitated Co-Design Studies with Children Focused on Socio-Emotional Experiences. In *Interaction Design and Children*. 37–49.

[77] Julia Woodward, Feben Alemu, Natalia E. López Adames, Lisa Anthony, Jason C. Yip, and Jaime Ruiz. 2022. "It Would Be Cool to Get Stampeded by Dinosaurs": Analyzing Children's Conceptual Model of AR Headsets Through Co-Design. In *CHI Conference on Human Factors in Computing Systems*. 1–13.

[78] Svetlana Yarosh, Anthony Tang, Sanika Mokashi, and Gregory D. Abowd. 2013. "almost Touching": Parent-Child Remote Communication Using the Sharetable System. In *Proceedings of the 2013 Conference on Computer Supported Cooperative Work* (San Antonio, Texas, USA) *(CSCW '13)*. Association for Computing Machinery, New York, NY, USA, 181–192. https://doi.org/10.1145/2441776.2441798

[79] Jason Yip, June Ahn, Tamara Clegg, Elizabeth Bonsignore, Daniel Pauw, and Michael Gubbels. 2014. " It helped me do my science." a case of designing social media technologies for children in science learning. In *Proceedings of the 2014 conference on Interaction design and children*. 155–164.

[80] Jason Yip and Kung Jin Lee. 2018. The design of digital learning activities for libraries through participatory design. In *Reconceptualizing Libraries*. Routledge, 203–216.

[81] Jason C Yip, Tamara Clegg, June Ahn, Judith Odili Uchidiuno, Elizabeth Bonsignore, Austin Beck, Daniel Pauw, and Kelly Mills. 2016. The evolution of engagements and social bonds during child-parent co-design. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. 3607–3619.

[82] Jason C Yip, Kung Jin Lee, and Jin Ha Lee. 2020. Design partnerships for participatory librarianship: A conceptual model for understanding librarians co designing with digital youth. *Journal of the Association for Information Science and Technology* 71, 10 (2020), 1242–1256.

[83] Jason C Yip, Kiley Sobel, Caroline Pitt, Kung Jin Lee, Sijin Chen, Kari Nasu, and Laura R Pina. 2017. Examining adult-child interactions in intergenerational participatory design. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. 5742–5754.

[84] Panayiotis Zaphiris, Giorgos Zacharia, and Meenakshi Sundaram Rajasekaran. 2004. Distributed construction through participatory design. In *E-education applications: Human factors and innovative approaches*. IGI Global, 164–179.

A SUPPLEMENTARY MATERIALS

A.1 Demographics of child participants

Child Name (Anonymized)	Age	Gender	Ethnicity	Years in WeDesign	Project Years Active
Quinn	10	Boy	White	4	2020 - 2021; 2021 - 2022
Brooklynn	8	Girl	Black / Asian	2	2020 - 2021; 2021 - 2022
Roman	11	Boy	Asian	4	2020 - 2021
Andreas	10	Boy	Latin American	4	2020 - 2021; 2021 - 2022
Sonja	12	Girl	Asian / White	2	2020 - 2021; 2021 - 2022
Avery	8	Girl	Asian / White	2	2020 - 2021; 2021 - 2022
Theo	8	Boy	Asian / White	2	2020 - 2021; 2021 - 2022
Ernest	10	Boy	Asian / White	3	2020 - 2021; 2021 - 2022
Cal	9	Boy	Asian / White	2	2020 - 2021
Harper	10	Girl	White	1	2020 - 2021
Katelyn	9	Girl	White	1	2021 - 2022
Desirae	11	Girl	White	1	2021 - 2022
Raj	9	Boy	Black	1	2021 - 2022

A.2 Description of the 20 Co-Design Sessions that Explored the Toio Robots for Telepresence

Design Session	Activity/Prompt	Robots?	Physical Prototyping?	On-Screen Collaboration?
0 - Tabletop Robot Ideas	Fold paper boxes to represent the telepresence robots, then come up with ideas for what they might do.	No	Yes	Yes
1 - Robot Introduction	Unbox the Toio robots, share first impressions, and practice moving them with the Toio console.	Yes	Yes	No
2 - Telepresence Introduction	Connect the robots to the Surface tablet via the web application. Practice controlling robots locally and remotely.	Yes	No	No
3 - Robot Practice	Adapt Olympic sports for the robots to play. Create accessories you need to play (eg., stage, attachments), then play the sport together using the robots.	Yes	Yes	Yes
4 - Maze with Marbles	Create a maze for the robots to move marbles around by rearranging and modifying laser cut maze parts designed and provided by facilitators. Then, use the robots to test the mazes you make.	Yes	Yes	No
5 - Drawing Together	Design a way to attach a pen to the Toio robots, then draw pictures with them for teammates to guess.	Yes	Yes	No
6 - Controller	Re-design the web application using either craft materials or on-screen collaboration software.	Yes	Optional	Yes
7 - Storytelling	Write a story for their robots to act out, then use the robots to tell the story. Optional: design costumes and stages to help set the scene.	Yes	Optional	Yes

8 - Absolute Control Pracice	Practice using the new feature to control the robots (absolute control using play mat). Optional: Children use this feature to teach adults a dance.	Yes	Optional	No
9 - Dance	Connect to someone else's robot remotely and dance with the robot. One child selects the song (DJ), the oth - er children work together to choreograph a dance.	Yes	Optional	No
10 - Emotions	Act out emotions that the robots can express. Optional: play charades with the robots	Yes	Optional	No
11 - Ideas for Robots	Generate ideas for what we should do next with the robots? Now that you are familiar with them, what do you think they are good for?	Optional	Optional	Optional
12 - Making Controllers	Design a physical controller (eg., handheld) that you can use to control the robots remotely and locally.	Optional	Optional	Yes
13 - Buttons	Express yourself or dance with the robots and/or share feedback on a new feature (expression buttons).	Yes	Optional	No
14 - Two Robots	Try using two windows logged into the web application to control two robots at once. Optional: Use the new controls (including absolute control and expression buttons) to tell a story.	Yes	Optional	No
15 - Online Controller	How might Zoom and the robot controls look if we combined them into a single interface? What features are missing in the current application?	Optional	Optional	Yes
16 - Video Chat	Provide feedback on different web applications that use video calling in interesting ways. Are their features that should be integrated into the robot app?	No	No	Yes
17 - Robot Soccer (Hybrid)	Work together to design a soccer field for the robots.	Optional	Yes	No
18 - Misinformation (Hybrid)	Tell stories about misinformation using the robots. Or, think of ways that the robots might be used to be deceptive.	Yes	Optional	No
19 - Controllers (Hybrid)	Look at and/or test out the new robot control UI that includes video calling. Share feedback on sticky notes. Optional: sketch alternative design ideas.	Optional	Yes	Optional