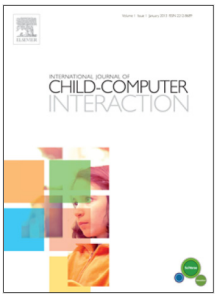

Pushing boundaries of co-design by going online: Lessons learned and reflections from three perspectives

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Highlights

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- Case studies of Online Participatory Co-Design

- Future of Co-Design with Children

Pushing Boundaries of Co-Design by Going Online: Lessons Learned and Reflections from Three Perspectives

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Abstract

The global COVID-19 pandemic made significant changes to our day-to-day lives, which impacted how we conduct research and design – including co-design. In this article, we present case studies from three different co-design groups that pushed the boundaries of traditional co-design, and conducted multiple co-design sessions (more than 150 total) over the last year and a half. The case studies for each team include: the transition to online co-design; the pros and cons of logistics and design tools utilized during the co-design sessions; and the advances, challenges, and surprises. We compare and contrast themes that emerged from the case studies and present additional dimensions that need to be addressed as researchers utilize online co-design and advance methods to conduct online co-design.

Keywords: keyword one, keyword two
PACS: 0000, 1111
2000 MSC: 0000, 1111

1. Introduction

Of necessity, due to the global COVID-19 pandemic, co-design with children has changed dramatically over the last year as it has shifted completely online. While co-designing online has previously been discussed in the literature [1, 2], implementing co-design sessions online over the last year and a half has led to experiential data that can lead to insights into future possibilities in designing with and for children [3]. In this article we address the research question of what we have learned from conducting cooperative inquiry online. To do so, we present three case studies of research groups that traditionally welcomed children into a physical space to conduct co-design sessions and how these three groups pushed that traditional boundary and transitioned to online co-design. These case studies, representing groups from three different regions in the United States, provide insights into online co-design including who participates and how they participated. The teams collectively conducted more than 150 online co-design sessions. We share these three case studies of transitions and active co-design over a period of more than a year, highlighting logistic and design tools, advances, surprises, levels of participation, and challenges each team experienced. We then compare and contrast themes from each case study relating it back to the literature.

We look towards the future of participatory co-design with children by revisiting how assumptions previously established for in-person settings became more readily apparent in online settings and how assumptions need to be revised to better accommodate online collaboration. These ever-shifting assumptions push the boundaries of who can participate and how children and adults can effectively work together in designing technologies for and with children in the future. The seemingly forced expansion of boundaries imposed by the global pandemic has enabled us to forge a new path that can not only add to our co-design methodologies, but can illuminate a possible future where combinations of online and face-to-face interactions could lead to more effective and inclusive co-design with children.

In the following sections, we address related work, describe the method, present the case studies for each team, then discuss the commonalities and differences between the teams' implementations of online Participatory Design (PD). We conclude with a discussion of the vision of the future of co-designing technologies for

and with children based on these experiences and feedback from our collective child and adult design partners. This includes additional dimensions that should be considered and addressed in order to effectively conduct and expand the research in online co-design.

2. Related Work - Online Co-Design with Children

Online and distributed participatory design (DPD) is an emerging subfield of PD pertaining to how physically or temporally distributed design teams coordinate activities to ensure equitable participation [2]. Although DPD has been previously discussed in workshops and panels [4, 5, 6], and has been available for quite some time, progress has been slow [7, 8, 9] and it has not been broadly adopted in the domain of PD with children, principally cooperative inquiry [10, 11]. With the globalization of the world's society and a vision to extend PD's inclusive reach across geographic boundaries, arguments have been made to further advance children's collaboration tools to enable distributed co-design [12]. While these have been important first-steps in advancing the notion of distributed, online co-design, they have not been broadly adopted. DPD with children has only been the focus of recent scholarship, with discussions on the possibility of conducting Video-CoDesign and eCoDesign [11]; early tools like DiSCO [1] that enabled the facilitation of the layered elaboration design technique [13], online and asynchronously; and recent workshops within the last couple of years seeking to construct the world's largest participatory design project [14], and others [15, 16, 17].

2.1. Advances Conducting DPD With Children

The primary advantage of online PD is the potential to include children of diverse cultures, languages, and abilities [16]. Children who may have been unable to participate previously due to transportation limitations, location, and access may now be able to take part [18, 2]. International collaborations are now made possible [19], and children who have special needs or who find social interaction difficult may find DPD less intimidating than in-person participatory design [2]. With the transition to online, entire households could now be included in the sessions [18]. Prior to the pandemic parents were suspicious about children's additional exposure to technology but generally shifted their mindset once the pandemic began to encourage their children's digital literacy skills [18, 2] and exposure to a wider array of technologies [2]. Additionally, apprehension about engaging in online methods and technophobia was reduced with the transition online [20]. Children are given more independence and privacy, with the ability to turn off their cameras and microphones and work individually through activities [2], and children could use the private chat function with a facilitator to express themselves—which may not have been possible in a physical setting [18].

2.2. Challenges Conducting DPD With Children

While there have been advances and benefits to conducting DPD with children, it is necessary to consider challenges that are brought about through the transition. A common obstacle in Child-Computer Interaction (CCI) and PD is how to include diverse and marginalized children [14, 12]. Digital divide issues [21, 22] such as connectivity, device access, and audio-visual problems are foregrounded [18] in DPD and children from lower socioeconomic backgrounds might feel alienated and disengage [2]. Even when using the same video conferencing software, some children use their phones as opposed to desktops, some do not have the latest software updates [3], which complicates their participation, like struggling to access links shared in the chat [19]. Although PD aims to level the playing field [10, 23], DPD introduces power imbalances through the increased involvement of adults, both parents and facilitators. Adults manage children's technology or children depend on adults for technical support [2], and dedicated time for parents to work with their children is a luxury [24]. Additional social challenges include the lack of connection and ability to build trust and rapport with children [2], especially when the children and facilitators have not met previously in-person.

In terms of engagement and focus, it can be difficult to recognize disengagement when children's cameras are turned off and non-verbal cues cannot be picked up [2, 25]. Even when children are engaged, the limited feedback from participants on what they are doing and how they feel is a challenge for facilitation [25]. Some children may dominate the screen [2] and some partners may not be attuned to online etiquette, such as muting microphones and using chat functionality instead of talking over other participants [20]. There are additional distractions at home [19] and the possibility of incidental participants [16].

With regards to logistics, DPD faces further challenges. DPD is a slower process [2] and unexpected situations and disruptions are likely to occur requiring improvisation [3]. Thus, more patience, time, and spontaneity should be allocated to the sessions [19, 16, 3]. There should be no more than two children per adult

[2, 19] and more facilitators are needed to run breakout rooms [20]. Along a similar vein, running multiple breakout rooms simultaneously may produce more data and require more analysis [20]. Many online collaborative tools such as Miro are not designed with children in mind, and even those designed for children may not be suitable to the design activities [2]. The challenges introduced by these tools exacerbate children's struggles with ideation and may lead them to misunderstand their role in the design process [2, 26]. Lastly, there is a need to consider additional ethical standards when conducting DPD with children [3].

2.3. Hybrid Techniques for Cooperative Inquiry

When co-designing with children, methods and tools that bridge the physical with the digital, online and offline, and synchronous and asynchronous are still in their nascent stages. One example of a hybrid approach is the "micro-event" organized by Constantin et al. whereby workshop participants teleconferenced with a classroom of socially-distanced children in the UK [2, 14]. Other potential hybrid methods include remote paper prototype testing [27], Machine Learning (ML) tools [2, 16, 28], cards to scaffold reflection [25], and "PD in a box" methods [24] akin to Cultural Probes [29]. In "PD in a box," design packs are sent to children prior to sessions containing materials in addition to "fun stuff" that can support team cohesion [30, 2]. However, paper-based PD approaches are inefficient when working with widely distributed partners [7] and thus online tools in the form of groupware [8] are needed. There are ongoing considerations for new remote communication tools [24] such as virtual characters to support idea generation [15] and platforms that work synchronously and asynchronously [31], as well as non-technical tools for conducting participatory design [2, 32]. Asynchronous DPD and hybrid sessions can be especially useful for younger children and children with special needs as it can allow them more time for sensory processing, task completion, and breaks [2]. However, one caveat of hybrid sessions is that partners participating virtually may feel like outsiders compared to their counterparts participating face-to-face, and may also face additional technical barriers like connectivity issues [20]. In our case studies, all three teams conducted DPD *synchronously*, which we refer to as online co-design in this article. In future participatory design sessions, we hope to explore more asynchronous and hybrid possibilities.

3. Method

The primary method or approach used herein is a reflection of the participatory processes used by three teams. It is analogous to the reflective approach taken in a previous article in the International Journal of Child-Computer Interaction where cooperative inquiry is revisited, assumptions are clarified, and the future of co-design processes are discussed based on the reflection [23].

As part of the reflective process conducted to address the primary research question of understanding the experiences of online cooperative inquiry, each design team revisited their schedules and notes from the design sessions they conducted online over the last year and a half. While there were variations in the total number of sessions conducted online for each team, overall, each team conducted between 46 to 65 online design sessions for a total of more than 150 online co-design sessions. Researchers from each team met synchronously online eight times (using Zoom) to discuss their observations and perspectives. During each of these synchronous sessions, collaborative notes were taken including a list of themes that emerged from our discussions. Through these several joint discussions, and individual and group asynchronous work, the researchers (and co-authors) iteratively refined a framework for the presentation of the case-studies that would focus on logistics and design tools, advances, challenges, and surprises. The case studies in the next section utilized this general framework. The description of the case-studies along with the themes identified during our collaborative discussions online were used to form the common and differing themes that are discussed in Section 5.1.

4. Case Studies

In the following sub sections, each team presents information regarding the specific context and demographics, logistics and design tools, surprises, advances, and challenges.

In order to contextualize the perspectives of these teams it is important to understand some of the historical and logistical commonalities amongst the three teams. First, the directors of these teams (and co-authors) have been conducting participatory design – particularly cooperative inquiry design – with children for more than 10 years each, with some for as long as 18 years. Prior to the COVID-19 pandemic all teams met twice a week in person in a child-friendly lab environment in the afternoon after school (generally meeting

(a) CoDesigning face-to-face, in the same physical space.

(b) Distributed, online setting.

Figure 1: Co-design in physical, face-to-face setting (1a) and online co-design via Zoom (1b).

4:15-5:45 pm). Each team consisted of six to ten children with a variable number of adult members attending each session (usually two to five, but sometimes more depending on the project). As described later in Section 4, each team lives in a geographically different location in the United States. Demographic information is provided for child participants of each team including a pseudonym, gender, age, race/ethnicity, and mode of participation. While not all demographic information is discussed in detail (e.g. race/ethnicity), this information adds context to the composition of each team and also aligns with the diverse regional demographics of each team. Adult participation was vast and would have more than doubled the size of the tables so due to space constraints these were not included. All of the teams transitioned quickly (within a few weeks) to an online meeting using video conferencing software (Zoom[1]; see Figure 1). The three teams are Kidsteam Maryland, Kidsteam Boise, and Kidsteam UW.

4.1. Kidsteam Maryland

4.1.1. Context & Demographics

This design team is geographically located in a large metropolitan area in the Eastern section of the United States. A total of 9 children aged 6-13 years old participated from Summer 2019 to Spring 2021, with boys outnumbering girls (6 boys; 3 girls). Seven of the children participated in both years, experiencing both in-person and online-only sessions. Of note, child partners in Kidsteam Marylandskewed older, which may account for some of the variation in design materials and techniques used throughout the transition to fully online co-design. Children's pseudonyms, gender, age, race/ethnicity, and the year they participated in are shown in Table 1. The children's race/ethnicity – all Black/African American – is over-represented in composition index [33] when compared with the local area (approximately 60% Black/African American [34]). In addition, six of the children are second generation immigrants to the USA, which is also an over-representation when compared with the region (approximately 15% of residents with at least one foreign-born parent [35]). This reflects Kidsteam Maryland's goal to increase the number of non-dominant youth (i.e., non-White, immigrant backgrounds [36]) who are exposed to – and have a voice in – technology design experiences.

4.1.2. Transition During COVID

For "Kidsteam Maryland," the transition from fully face-to-face co-design sessions to fully online co-design sessions was astonishingly easy: everyone was passionate about maintaining some sense of normalcy in the midst of an extremely abnormal and unsettling time. Our state's emergency declaration and move to "shelter in place" in response to the COVID-19 pandemic occurred one day before our university's regularly scheduled spring break holiday (which is usually a week off from classes). This allowed both the research team and participating families a week to re-group, to become acclimated to daily changing news feed and state-wide guidance, and start sharing our feelings and efforts to keep designing together. When our university and local school communities began to mobilize for fully online learning and remote work, we surveyed parents and children for their thoughts about continuing co-design sessions fully online. We were able to send snack boxes via the postal service or hand-deliver them and ran a "technology test" session within two weeks after the order to shelter-in-place. Kidsteam Maryland was back in session before most schools returned in online mode.

In terms of session structure, we followed our typical in-person session sequence, to engender a sense of normalcy. This decision was based on the early distributed co-design system, DisCo [1], which also directly mapped the typical in-person session structure to an online space. For example, we used Zoom digital whiteboards for circle time/question-of-the day, Google Jamboard[2] and/or Miro's digital whiteboard[3] to support various design techniques, such as sticky-noting (likes, dislikes, design ideas), storyboarding, and even online layered elaboration [13]. This format also underscored everyone's early desires to maintain a sense of normalcy and familiar routines.

4.1.3. Logistics and Design Tools

During the early "honeymoon" phase in which everyone was excited to be co-designing together despite the pandemic, our biggest challenge was finding ways

[1] https://zoom.us/

[2] https://jamboard.google.com/

[3] https://miro.com/

Pseudonym	Gender	Age	Race/Ethnicity	2019-2020 (Hybrid)	2020-2021 (Online only)
Perry	M	6	Black/African American		•
Blaine	M	7	Black/African American	•	•
Barack	M	8	Black/African American	•	•
Gina	F	10	Black/African American	•	•
Jaylen	M	10	Black/African American	•	
Penny	F	11	Black/African American	•	•
Alan	M	11	Black/African American	•	•
Deborah	F	11	Black/African American	•	•
Kevin	M	13	Black/African American	•	•

Table 1: Distribution of children across our co-design sessions.

to ensure that we all had a level playing field in terms of technology. Kidsteam Maryland opted to co-design with the children "as they were," taking advantage of an opportunity to learn about the technologies available in their homes "as-is." Although we initially considered acquiring tablets for each of the child co-designers, we did not augment any home/family technologies. In the end, children connected and co-designed with systems that they chose. Consequently, about a third/to one-half of the children used their own laptops or borrowed their parents'/family laptops, another third used laptops provided by their schools, and two children often used only their mobile devices to join our remote co-design sessions. In some cases, children participated using *multiple devices*, such as a laptop and a mobile phone.

Requirement to add dedicated "technology testing" and familiarization time to sessions. One task that we found absolutely necessary was to incorporate a dedicated "tech testing and training" session with both children and adults. Although we often include a technology immersion [10] session when we engage with new and emerging systems, we found it crucial for online co-design to dedicate one entire session to testing only (our first transition session). We tested everyone's cameras, screen-sharing capabilities, chat, and Google Jamboard. Our child co-designers seemed very engaged with the testing process, delighting in sharing the latest games they were playing via screen-sharing. This also afforded adult facilitators an opportunity to learn about the systems children were using to connect. For example, at one point, one child noted that he could not access a website we were testing, and we learned that he was using an old version of Internet Explorer[4] on his family's Windows-based PC. After some discussion, he was quickly able to switch to Google Chrome, but it did serve as an "a-ha" moment for the team regarding the potential range of applications that we would might have to navigate in the long term.

Broadband access and Tech-trouble-shooting We found that we had to deal with "digital divide" [22, 21] issues during every session, since several of our participating families had poor broadband WiFi connections. For the children who regularly used school-provided laptops, we sometimes had to manage firewall or related security privilege issues or poor audio (microphone) issues. For example, one child could not access a website that we had planned to evaluate. We had to ensure that we could build time into sessions, or prior to sessions, to test websites and apps, often giving parents a "heads-up" beforehand that we would be testing specific apps or websites (e.g., Messenger Kids[5], KumoSpace[6]).

Paper-based low-tech prototyping versus digital tools. Once we had transitioned to fully online co-design sessions, Kidsteam Maryland used very little paper prototyping, focusing on ways for the team to collaborate and co-design using digital tools. Although we mailed some low-fidelity prototyping materials in our initial snack boxes (e.g., markers, post-it notes, colored paper), children were most excited (initially) about trying digital tools. Our goal was to enhance collaboration by bringing everyone who was physically separated together through the design process. For this reason, we focused on gathering together around a digital whiteboard, rather than designing prototypes individually and then sharing them via camera screens. In this case, our digital tool became a boundary object [37, 38, 39] around which sub-groups and then the whole team could gain a sense of togetherness and teamwork, despite the physical separation.

Physical presence, digital proxies, and social connections. Every semester, Kidsteam Maryland engages in a retrospective session where we reflect on our growth as designers and all the design questions that we have tack-

[4] https://en.wikipedia.org/wiki/Internet_Explorer

[5] https://www.facebook.com/messenger_kids_marketing/

[6] https://www.kumospace.com/

led over the previous several months of our university's academic year. Interestingly, in the spring of 2020, children selected more photos and memories of their physical co-design sessions to share with parents. In contrast, the memories they chose to share from online sessions were all social in nature. For example, several of the children found screenshots where everyone was crowded within and "playing around" Mozilla's Social VR space (see Figure 2). Often, the children juxtaposed photos of avatar crowds with photos from pre-pandemic scavenger hunts and ideation sessions with cardboard boxes [40]. Social VR transformed the phrase "social distancing" into a misnomer: our avatars were not "just" digital proxies of our physical selves, they enabled a sense of sociability and closeness despite our physical separation.

4.1.4. Advances

Despite facing the challenge of managing multiple technology configurations and connections and despite feeling a loss of physical presence, we still learned a great deal about the resilience and creativity of our team during our transition from fully face-to-face to fully online. In particular, our child co-designers often took the lead to troubleshoot technical difficulties and to make suggestions for expanding the suite of tools and techniques we used. We experienced several teachable moments how to share, communicate, and collaborate through an extra layer of technology. We also appreciated the opportunity for a more intimate view of our co-design teammates' homes and family life.

Technical 'blips' often promoted collaboration and creative trouble-shooting. As noted earlier, the shift to conducting co-design entirely online was met with excitement at the onset of the transition, with the use of virtual spaces such as the Social VR tool, Mozilla Hubs[7] helping drive some of the enthusiasm. Most of the children became quite adept at trouble-shooting potential connectivity and device compatibility issues. For example, when one boy found his mobile view of Zoom resulted in fewer menus options and limited features, he quickly shifted to using both his mother's laptop and his mobile phone to participate in the session. Similarly, when one child was unable to navigate to the Mozilla Hubs URL on his mobile device, he enabled remote access via Zoom to his adult co-design partner, and together, they were able to help him get set-up.

Opportunities to practice collaborative social norms and more balanced child-adult power dynamics. In lieu of our traditional face-to-face snack time, which provides an opportunity for children to get much-needed snacks between a formal school setting and active co-design, Kidsteam Maryland gave the children screen control to share their latest games and toys with the group. This empowered the children to share their screens as they liked, and to practice turn-taking as well. In addition, when designing in breakout rooms, they could also share their screens instead of the adults. While this could sometimes become challenging, as some children would rush the group or work individually, it also gave them opportunities to lead as active participants in the design conversation. From a social norms perspective, we maintained the same child-adult co-design practices that we had in-person, but we often emphasized them more explicitly online, since we lost a sense of presence. In particular, given the range of systems that children used to connect, we tried to make time to let the children decide what worked best for them when working in small group breakout rooms. We invited them to share screens if they preferred, and they would usually acknowledge their inability to open links to shared applications or their enthusiasm to control the screens.

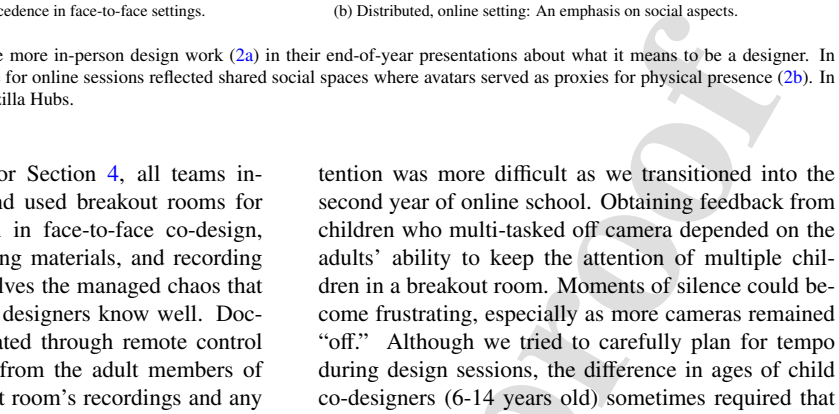
4.1.5. Challenges

Technology-mediated design. Despite the creative and collaborative ways that we learned to tackle technical glitches as a team, we still encountered challenges with simple session management. Even if there are no technical glitches or connectivity issues, basic online design tasks like managing the logistics of moving to breakout rooms and recording multiple feeds is trickier when mediated through a remote interface. Some children needed help transitioning to breakout rooms (especially if they only connected with their mobile devices), while others had to wait for their partners to transition. The more children had to wait for small group transitions, screen sharing click-throughs, or troubleshooting glitches, the more likely ideation would lose its spark. Simple collaboration features could become double-edged swords. For example, Zoom chat often enabled all co-designers (children or adults) to respond to design prompts when their audio was not working (or without interrupting others). Chat could also serve as a back-channel means to be sociable (e.g., texting "hi!"). However, chat was also used to get attention or disrupt conversation. For example, at times, younger children elected to "spam" the chat channel, obscuring shared links or productive comments if they felt their ideas were not recognized.

Logistics management overhead increased. As in-

[7]Mozilla Hubs site: https://hubs.mozilla.com/

(a) Design materials take precedence in face-to-face settings.



(b) Distributed, online setting: An emphasis on social aspects.

Figure 2: Children chose to share more in-person design work (2a) in their end-of-year presentations about what it means to be a designer. In contrast, the salient design feature for online sessions reflected shared social spaces where avatars served as proxies for physical presence (2b). In (2b), children collaborated in Mozilla Hubs.

dicated in the overview for Section 4, all teams including Kidsteam Maryland used breakout rooms for small group work. Even in face-to-face co-design, moving to groups, managing materials, and recording field notes or artifacts involves the managed chaos that child-computer interaction designers know well. Documentation logistics mediated through remote control demanded more attention from the adult members of the team, as every breakout room's recordings and any shared artifacts were managed by each adult (or adults) working in each breakout room. Shared document management had been used to archive design data *before* the transition, but was crucial when we were fully online. Again, technology proved a double-edged sword: we were able to record the co-design process in more detail, but it was still through a specific technology lens, often largely controlled by an adult's screen-sharing and dependent on adult logistics management. Similarly, certain "design logistics" activities required more independence of the children (e.g., children navigating to websites based on URLs on their own).

Challenges related to social norms mediated through technology. Over time, the biggest challenge we faced was more social than technical: sustaining online sessions over an extended period of time (months!) was difficult. Given that social interactions in almost every aspect of our lives were filtered and funneled through a remote connection, children either had to be "always on camera" for school, or far removed from the tangible, physical play critical for their well-being. Child design-partners would often tell us that they preferred leaving their cameras off, because it felt less mandatory and "less like school." Gradually, Zoom "camera-off" social norms emerged, resulting in a checkerboard of black or grey boxes and still images with names in block letter font. The voices were the same, but our sense of presence was a bit lost.

We also found that children multi-tasked more often during sessions, whether due to connectivity troubles, distractions from family members in their home environment, or dark cameras that afforded split attention between the online design session and their home environments. In some cases, older children apologized, but still mentioned that they had to finish homework while also trying to participate. Keeping track of divided attention was more difficult as we transitioned into the second year of online school. Obtaining feedback from children who multi-tasked off camera depended on the adults' ability to keep the attention of multiple children in a breakout room. Moments of silence could become frustrating, especially as more cameras remained "off." Although we tried to carefully plan for tempo during design sessions, the difference in ages of child co-designers (6-14 years old) sometimes required that older children wait for, or take time to support, younger children.

In many cases, we found that interaction through a shared digital interface (e.g., whiteboard) increased our ability to nudge younger children to collaborate. In other cases, however, sharing a digital whiteboard also enabled children to opt to destroy others' ideas if they were frustrated or if they felt their individual ideas were not being recognized. For example, during an ideation session with the digital whiteboard, Miro[8], one child decided to delete one of our design templates, along with several ideas posted on digital post-its, just prior to their group's turn to share back ideas to the larger team (and despite the adults' preparations to lock-down most of the templates). We were able to recover the ideas through our recordings, but several team members – children and adults – were disappointed and frustrated. We worked to recognize the younger children's ideas and stress the importance of collaboration, as suggested in prior work where technology features supported face-to-face collaboration (e.g., [41]; however, younger children often found the shared digital workspace challenging when compared to their ability to control their own physical prototypes in face-to-face sessions. We noticed an increased tendency for our younger child partners to try to control the design space, cover others' ideas, or "spam" the chat after the children had been attending school and co-designing online for almost a year.

Challenges related to design roles. Some technologies we designed online shaped children's design roles. Children took the role of design partners in all sessions that involved a gamified and digitally embodied experience, such as virtual reality platforms like Kumospace or Mozilla Hubs. Children were more engaged in discussions, and their presence in physical participation

[8] https://miro.com/

was apparent and made more possible thanks to the embodied experiences these technologies enabled. In many cases, children's design ideas and interactions through avatars served as proxies for the loss of physical materials that we used in face-to-face co-design.

However, the added layer of remote communication and collaboration mediation often constrained the children's ability to take on roles beyond tester or informant. When the children's interactions were limited not only to navigating web-pages, but also communicating their actions through yet another interface, children tended to remain in the roles of informants or testers. In some cases, this was due to the design goal (e.g., playtesting or evaluation); however, sessions that afforded a more embodied sense of interaction yielded more playful engagement and a higher volume of discussion and ideation.

4.1.6. Surprises

Expanding design space boundaries. When we transitioned to fully online co-design, we knew that we would be connecting with children across geographic boundaries. What we did not foresee was how expansive our design space could become. Rather than working together in one large physical room in-person, our workspace expanded into each co-design partner's home. We still gathered around a whiteboard as a whole group during our question-of-the day warm-ups, but now our whiteboard was both mediated through small screens and was almost infinitely expandable, by zooming in and out of focused areas. Our small group work was not only bound in break-out rooms with little of the familiar cross-chatter we experienced in our physical space. We also worked with children as they fidgeted in playrooms, whizzed around a family room on a scooter, or tried to multi-task on homework at their kitchen tables.

Enabling participation across large geographic boundaries. The transition brought surprises about the ingenuity of our child collaborators and also underscored DPD's early promise of increased inclusion of geographically remote participants [1, 2]. During the pandemic, unbeknownst to the adult co-designers until several weeks into the transition to online, one of the families moved to another state, several hundred miles away. We were only able to confirm the move when the team was discussing what snacks we should send (via mail) for an upcoming celebration. The childrens' access to sessions and interaction during sessions had changed little – we still met at the same time, used similar design tools (e.g., digital whiteboard, web-browsers, etc). The actual point from which the child connected did not impact these interactions at all. Imagine our surprise when the child revealed to the adult co-designers that her desire to maintain a sense of normalcy was so strong, she simply attended design sessions as usual. In addition, our adult co-designers collaborated across geographically distant locations, connecting from multiple states and at some points during the year, multiple countries and timezones.

Child-Adult power balance: new-found leadership opportunities. As noted in Section 4.1.4, online co-design often shifted child-adult power dynamics in unexpected ways. Typically, children had more autonomy to decide how they wanted to collaborate and interact with their team mates because they were at home, not in our university lab. This power shift also extended to the tools that children recommended and even implemented for the team. For example, during most of our year of online co-design, the adults used multiple communication channels (e.g., chat/text messages, email, remote videoconferencing via Zoom), while the children primarily interacted via Zoom. After we had all grown accustomed (and even fatigued) with Zoom and had evaluated a variety of videoconferencing (e.g., KumoSpace), we asked the children to share more of their favorite online spaces and social media platforms. Several children (even those as young as 8-9 years old) mentioned the social media platform, Discord[9], as a favorite. We knew anecdotally that Discord was popular, and several adult researchers had used it with teens in other projects. Consequently, we asked parents if we could establish a Kidsteam Maryland Discord server, and ran tests with the children during our university's spring recess. All but the youngest child (6-year old) participated enthusiastically, and we began using the server to make team announcements, send zoom link reminders, and share fun social artifacts (e.g., favorite memes and emojis).

After a few weeks, one of our older child partners asked if he could redesign our team server. He added improved features such as a server "bot" to welcome users and promote interactions. He even initiated bot and meme-naming contests and made announcements like the adults. He also mentioned that he aspired to be an adult co-designer when he was older, like one of the undergraduate adult co-designers (who had been a child member of Kidsteam Marylanda decade before). In this case, Kidsteam Maryland's older cohort shifted the power dynamic such that they were the leaders rather than the adults.

[9] https://discord.com/

4.2. Kidsteam Boise

4.2.1. Context & Demographics

This design team is geographically located in a metropolitan area in a more rural state of the United States. There were ten children that participated in the online design team. Of those children, two of the children live in a more rural part of the area and had previously commuted to participate in the main city close-by. Three of the children joined online only – one joining in Fall 2020 was a sibling of other child design partners, and two joined immediately after the transition to online sessions. These latter two were children of an adult design partner and would not have been able to join due to timing and location if the sessions were not conducted online. Participants' demographics are listed in Table 2. As can be seen in the table, there is not a lot of diversity in terms of race and ethnicity which is similar to the overall population of the state with the exception of Hispanic populations who are in the area, but unfortunately not represented currently on our team.

4.2.2. Transition During COVID

For Kidsteam Boise, the transition from face-to-face design sessions to fully online was relatively smooth. The university's spring recess coincided with the university's decision to move to online courses and as such we had some time to work on the transition. We had a week and a half break from having our twice weekly sessions before starting our virtual design sessions. In that week and a half, to facilitate this transition and to reduce children's technology access issues, we purchased Kindle Fire 8 HD tablets with 32 GB storage, 4 GB RAM to all child design partners. In addition to tablets we also prepared supply bags that were dropped off at children's homes with Kindle tablets. These bags included arts and crafts supplies, sticky notes, clipboards, pens, paper, journals, markers, etc. We scheduled our virtual design sessions so they followed the same schedule used in conducting face-to-face sessions so they occurred Tuesdays and Thursdays 4:15 - 5:45 pm.

4.2.3. Logistics and Design Tools

During the virtual design sessions, we initially used a lot of physical design activities including arts and crafts and sticky notes that children were already accustomed to using in the face-to-face sessions. In conducting online sessions there were several logistical and design tool decisions that we made. We share some of those below along with some of the advantages and challenges of each.

Uniform technology setup. As indicated above, we decided to provide a uniform hardware platform (Kindle Fire tablet) for children to use along with pre-installing a set of apps like Zoom[10], Google Photos[11], Google Slides[12], Google Chrome[13]), Jamboard[14]. All other apps were placed in a folder that was password restricted (using an app). This had some advantages as we could (theoretically) synchronize all pictures of artifacts in the background (as all tablets used a shared account), but in practice pictures did not always synchronize and sometimes children used a different platform to connect (e.g., a home or school computer).

Videoconferencing (Zoom). Like the other teams, we used the Zoom video conferencing tool to meet with design partners. The lead researcher pre-scheduled all the Zoom meetings, which helped to streamline the design sessions and shared a Google Calendar event with all meeting information with the parents of the children. All tablets had a laminated card with the Zoom join instructions for sessions. This facilitated joining, although there were some technical challenges faced when the tablets exited children from the Zoom sessions (this seemed to only happen with children joining from tablets).

Transition time: Maintaining power dynamics. An important aspect of cooperative inquiry in face-to-face settings was an informal snack time where team members (children and adults) connect informally. Afterwards, as an introduction to the day's design activity, and often throughout the design activity, children and adults sit together on the floor. Instead, during the virtual design sessions, for the first 15 minutes of the design session, we asked children to share something interesting that they would like to share with the group to provide an informal transition to working as a team. Due to differing power dynamics in the online environment (e.g., children can turn off their cameras) sometimes it was hard to feel a sense of connection.

Break-out rooms for smaller group activities. Within the conferencing ecosystem, we frequently utilized the breakout rooms functionality to facilitate small group work. Usually, one adult worked with two-child design partners in a group. The adult design partner in a group helped child design partners navigate the technology, the design process, and also took notes about the design ideas produced from the child design partners. We initially used the timed breakout functionality, but quickly realized we needed much more flexibility in

[10] https://zoom.us/
[11] https://www.google.com/photos/
[12] https://www.google.com/slides/
[13] https://www.google.com/chrome/
[14] https://jamboard.google.com/

Pseudonym	Gender	Age	Race/Ethnicity	2019-2020 (In-Person)	2020-2021 (Online only)
Rose	F	6	White		•
Francesca	F	7	White		•
Dexter	M	8	White		•
Cody	M	8	White	•	•
Kayla	F	9	White	•	•
Dakota	F	10	Asian	•	•
David	M	10	Asian		•
Emily	F	11	White		•
Andrea	F	11	White	•	•
Daisy	F	11	White	•	•

Table 2: Distribution of children across our co-design sessions.

the timing of our breakout sessions.

Physical artifacts. We used a lot of physical artifacts that the children were used to using in the face-to-face sessions. We explored the use of virtual sticky note applications and shared drawing tools, however, in order to simplify the process we utilized physical paper and sticky notes, and the facilitator coordinated ideas amongst the groups. Children presented and took pictures of their ideas at the end of each design session. The primary techniques that we used during our online sessions included: sticky notes, bags of stuff, and designing on paper; for brevity we share how we utilized sticky notes here. In the university lab setting, children would stick their sticky notes on a large whiteboard (as shown in Figure 3a). In the online co-design setting, in addition to adult taking notes in the break-out rooms, children presented and took pictures of their likes, dislikes, and design ideas at the end of each design session (as shown in Figure 3b). We found it challenging sometimes to get children to work on other's ideas and collaborate, and so more facilitation was required by adult design partners.

Shared Notes Area and adult coordination during sessions. Having shared notes allowed adults to dynamically collaborate and combine group design ideas. For each session, we used a shared Google Doc[15] that had the agenda for that day and was also used as a space to take notes. Extensive notes in a shared collaborative environment were required to capture the process in the online setting in order to better document design ideas and facilitate collaboration among and between small groups. We also utilized this document to capture and validate the big ideas from the session (with adults and children design partners), and to identify next steps. This documentation made it possible to better revisit the design decisions and directions from each session. Oftentimes, adults need to coordinate and make micro-adjustments during a design session. In order to facilitate this communication, all adult design partners communicated via a shared Slack channel during the sessions to coordinate issues that arose, including small group work coordination and technological troubleshooting.

High adult to child ratio. In comparison to design face-to-face design sessions, adult facilitators in online sessions were busier switching between tasks (and technologies) and were not able to focus on just facilitate collaboration. Adults attention was required to: troubleshoot technology, facilitate design activities, take copious notes, communicate via back-channels, confirm artifacts were being captured properly, and more. With these increased attention demands, we found it necessary to have a higher adult to child ratio – typically 1 adult and 2 children in each breakout session.

Extra patience, & time for activities, flexibility, and shorter sessions. Because of the additional demands on child and adult design partners, more patience, grace, and understanding was required for all involved. We realized that sometimes children just needed more time to develop, work-on, and share their ideas. It was sometimes challenging as children would have their videos off and would not respond to audio prompts so it was hard for adults and their peers to know what they were doing and/or thinking. While we initially scheduled sessions similar to how we would face-to-face sessions, we quickly realized that we needed to allow more time for each design activity. In particular, we needed to allow more time to transition between large-group and small-group activities. There were situations where children faced some technical issues while being part of online sessions, and the extra time helped us mitigate the technical issues. Technical issues included WiFi connectivity issues, and tablets not being adequately charged. Additionally, in face-to-face sessions, the pacing seemed

[15] https://docs.google.com/

more uniform, and we found that in online sessions, sometimes a group or individual needed more time to process and create, articulate, and share their ideas. In addition – perhaps paradoxically – we realized that attention spans were shorter and sessions needed to be shorter. In making sessions slightly shorter and providing more time to allow ideas to percolate, at times it felt like sessions overall were less efficient (in terms of the volume and quality of ideas) than face-to-face sessions.

4.2.4. Advances

A few advances were noted with regards to designing online. One of the primary advantages was the inclusion of children who otherwise would not have been able to participate. While we only had a few people add on during the completely online sessions, they otherwise would have been unable to participate. This opens doors to including a broader array of participants and design perspectives.

Additionally, as noted above, extra patience, time for activities, and flexibility required us to focus more and clearly identify the central topic for each session. While for those that had experienced face-to-face design sessions it seemed like less was accomplished overall, there are advantages to having a more focused session.

4.2.5. Challenges

All children from Kidsteam Boise were very excited to participate in the initial few online design sessions. After three months into virtual design sessions, the excitement level dropped. In addition, children faced network connectivity, device charging, Zoom version, and Google photos sync issues. Having network issues led children to drop out from the Zoom session abruptly. In some sessions, children were dropped out of the session multiple times. Unfortunately, we were unable to administer the tablets completely remotely, but were able to identify one issue was version incompatibility. We also encouraged children to recharge their Kindle batteries before attending each design session; although some children who failed to recharge their batteries dropped out the Zoom session unexpectedly. Sometimes they used another device or plugged in the device to rejoin. We asked children to take pictures of their artifacts and journal entries at the end of each session. Theoretically, these were then synchronized automatically from each child's device to a shared Kidsteam Boise account. In practice, we experienced several issues getting the pictures to synchronize to the shared account. It was unclear whether this was a limitation due to the budget tablets that were utilized or some other technical issue.

The online environment impacted – and perhaps seemingly limited – some of the topics that were addressed. To facilitate the transition from physically meeting together, we used a lot of tangible design techniques that were used in the design lab. This included "bags-of-stuff" [11] physical artifacts which were harder for people to collaborate with in on online setting. We also used online tools (e.g. Google Slides and Jamboard) but these often resulted (even with adult facilitation) in more individualized ideas that represented less collaboration than was witnessed in the collocated lab setting. As such, some of the projects that were pursued were biased towards projects that could be better implemented in this online setting such as social media applications, communication tools for collaboration, and conducting common cumbersome tasks in online settings (e.g. authentication).

4.2.6. Surprises

Throughout some of the many sessions that we conducted, we noticed several surprises, one of these included a very different power dynamic than existed in face-to-face co-design sessions. Additionally, and perhaps related, was that some children asserted more of a leadership role in suggesting and leading design topics.

Power dynamic differences. With regards to the different power dynamic, some of these related to some of the challenges that were experienced. While children had some reliance on adults to provide technological access and sometimes support, they also had more ability to make their own choices as to how they participated. For example, children realized they had more autonomy with regards to moving around their homes, turning on and off their cameras, walking away, etc. They engaged in conversation with one another in direct messaging on Zoom. All of these had some potential to distract others from the design experience (and sometimes did). During some sessions, we encouraged children to show their video stream and limited some chat behaviors allowing them to only publicly post messages (instead of direct messaging). As an aside, it was also surprising how even though children could engage directly through video, many actively engaged in textual conversations with one another via the chat feature on Zoom. This included copious use of emojis. It should also be noted that some children who identified themselves as not really liking to write still engaged heavily in writing messages to others.

Structural changes. While we initially attempted to use some of the same structures in an online setting, expecting that some adaptations would be required, we did not necessarily anticipate how the structures would

(a) Lab, face-to-face setting.

(b) Distributed, online setting.

Figure 3: Children using sticky notes in a university lab setting 3a and distributed online setting using physical sticky notes (3b). Team members each identified: *Likes, Dislikes and Design Ideas technique*. In (3a), all ideas were in a shared space; in (3b), child design partner used white paper as a board to separate likes, dislikes and, design ideas.

need to be changed. For example, we realized through experience in our online sessions with children that we needed to allot more time for some design activities and to allow children to work seemingly on their own. Additionally, we found that we could not always use the 90 minute block we had used in face-to-face sessions, as children would become tired and more distracted during online sessions. We also noticed that due to the seeming variability of engagement in activities and sessions (that depended on the day, not necessarily consistently across the children), we did not consistently follow the same routines we did in face-to-face settings with a journal entry and everyone leaving at the same time. Sometimes children needed to leave early and/or did not do a reflective journal entry.

Perhaps most surprising were the structural changes that impacted some of the power dynamics within the group. For example, in a face-to-face session we had limited rules, namely: (1) no raising your hand, (2) respect, and (3) have a lot of fun. The first rule, which is purposefully orchestrated to combat some of the traditional adult-child power dynamics, was challenging in an online setting as it was harder to read cues of others and naturally yield to one another in conversation. It was harder for some children to respect other's space as it was so easy to write or draw over other's designs in a shared digital design space. Due to these challenges, some children suggested additional rules, which were hard to encourage and enforce. This made it challenging to equalize the traditional power differences between adults and children and cultivate a sense of design partners.

Child observations led to new design topics, some led by children. Some children noticed the engagement challenges due to working together on an online platform and suggested the use of something like ClassCraft[16] to engage students. We conducted initial design sessions on this kind of an approach and quickly realized that the motivation system in ClassCraft did not appeal to all of the children on the team and instead started designing something that might work for our intergenerational design team. It was natural – yet a little surprising – that the children noticed these challenges and made direct suggestions towards trying to improve the collaborative environment during co-design sessions. Moving online shifted the focus of some of the topics the co-design team worked on, including how to better collaborate in online settings.

[16] https://www.classcraft.com/

4.3. Kidsteam UW

4.3.1. Context & Demographics

This design team is geographically located in a large metropolitan area in the Pacific Northwestern portion of the United States. A total of ten children (ages 7 - 11) participated from Spring to Summer 2020 and 13 children (ages 7 - 12) from Fall 2020 to Spring 2021 (Table 3). Children in this team had a range of experiences with co-design, from children that have only experienced co-design online, to children who have had both online, hybrid, and local experiences. The children also ranged from those living close to our university (2 - 6 km) to those living farther away (15 - 25 km). Participants' demographics are listed in Table 3.

4.3.2. Transition During COVID

For Kidsteam UW, our university runs on a quarter system and we ended the Winter 2020 session of face-to-face co-design in the middle of March 2020. The university cancelled all in-person meetings by mid-March 2020 and our team decided to pause the co-design sessions in April 2020 to figure out the best way to transition online. After a month of planning, we started again from May to July 2020 with one session per week to complete the 2019 - 2020 year. For the 2020 - 2021 year, we started in September 2021 with one session per week with returning and new children. After the Fall quarter, we transitioned to two sessions per week for the Winter and Spring quarters of 2021.

4.3.3. Logistics and Design Tools

Our team chose to use our university's Zoom account as the main meeting space. We chose Zoom because it was already used with children on a daily basis in their online school situation and that the meeting app could be hosted on a variety of devices (e.g., desktops/laptops, tablets, Chromebooks, and smartphones). We used a variety of online apps (e.g., Google Drive, Slides) and Office applications (e.g., PowerPoint) to setup our sessions. Sessions included a variety of online breakout

Pseudonym	Gender	Age	Race/Ethnicity	2019-2020 (Hybrid))	2020-2021 (Online only)
Akira	M	7	Asian/White		•
Sarah	F	7	Asian/White	•	
Ethan	M	8	Hispanic	•	•
Jack	M	8	Asian/White	•	•
Jin	F	8	Asian/White		•
Mia	F	8	Asian/White	•	
Moon	F	8	Asian/Black		•
Erin	F	9	White		•
Christina	F	10	Black		•
Hope	F	10	Asian/White	•	
Marcus	M	10	White	•	•
Suga	F	10	Asian/White	•	•
Alan	M	11	Hispanic	•	•
Ryan	M	11	Asian	•	•

Table 3: Distribution of children across our co-design sessions.

rooms with small groups and larger meeting groups. Because being in video conferencing could be physically and mentally draining [42], we chose to reduce our original time of 90-minutes in-person to 75-minutes online. In lieu of face-to-face designs, we shipped many arts and crafts (e.g., stickies, paper, markers, pens) to the children. We also remixed a series of physical co-design techniques to adapt to online environments (see Lee et al. [3])

4.3.4. Advances

Increases in diversity, equity, and inclusion. Because we chose to go online, we were able to recruit more children from farther away. Our university if located in an area that is racially and economically stratified. Children living closer to the university tend to be from more affluent families that could travel and bring their children to face-to-face sessions. Even living close to the university did not guarantee easy access onto campus with schedules. Similarly, we were never able to recruit from farther away because of transportation logistics and infrastructures. As mentioned before, children in our group lived both close and far to the university. Our city is racially and wealth stratified, with a history of racial housing segregation that still impacts where people live. The city here also has infrastructure challenges, such as few transit options and roads and bridges that need repair. Transitioning to online sessions, we were now able to have children from historically marginalized populations and children living far away participate in our team. For instance, two children (Moon and Christina) were located 17 miles (27 km) away from the university campus. Another girl (Erin) would not have been able to make it to campus because of a bridge that was under construction (1 hour commute). Two other children (Suga and Jin) lived near campus, but could not have come to our team without having an online option.

Discovering what home life is like for children. Children acted the way they wanted because they were attending co-design sessions from home. A child (Mia) in Kidsteam UW had a rope swing in her bedroom and would swing back and forth during co-design sessions. Another child (Hope) brought their pet lizard in a sweater to Kidsteam UW, while another child (Akira) showed off his chickens in the backyard. Other children would have sibling and parent spectators come together to watch the children. We overheard parental conversations at work, saw cello lessons in the middle of co-design sessions, etc. By seeing what their homes were like, we were able to have different kinds of conversations and connections with the children that we could not have done before. Before going online, we only had surface level understanding of home life, much like a teacher in a classroom. By seeing their homes, rooms, cars, and other connected spaces, we were able to draw on these contexts for our design.

New techniques modified and adjusted for online. Design techniques [43] had to consider a new set of questions [3] about how to best implement. A technology filter was added to all design techniques and ultimately changed how they were implemented online. Even drawing with pen/paper required a webcam, conference call, and screen capture for the technique to properly work. Technology had to be limited to two platforms (the conference call application and the whiteboard/browser/etc.). At the same time, design techniques in our team did not always stay virtual only. For instance, techniques that used voting procedures had to be redone in a way that all children could participate,

with or without their webcams on. Figure 4 shows examples of children engaging in online co-design using physical materials.

Discovering how project techniques, context, and interpretation need to be considered in improvisation of co-design. "Necessity is the mother of all invention (proverb)." As famously stated, these difficult times forced our team to reconsider every aspect of co-design that we took for granted. The goals of the design, the people and the settings, and how basic communication was interpreted all were subject to drastic shifts and changes during the session. As a result, we had to consider how any aspect could fluctuate during a session, while at the same time, making sure our own sessions could adapt to these changes. As a result, our team thought more closely about HCI improvisation [3]) as a critical piece of co-designing, especially online. These kinds of improvisations occurred more frequently than when we were in-person. Technical difficulties (e.g., slow internet, poor microphone) made it so that each session had to be reconfigured. Similarly, because children had more autonomy to stay or go, sometimes children would drop off the session without notice. This meant adults had to quickly reconfigure groups when some children were no longer present.

4.3.5. Challenges

Video cameras off all the time. A number of children, no matter what, wanted their video cameras off. Whether they were with our team most recently or years, some of the children had the tendency to keep their cameras off. For some children, it was about internet bandwidth, but for others it was about privacy. For example, children would try to physically prototype together, but some decided not to use the cameras to show the process of how the prototypes were being designed. Instead, children only showed their cameras when the adults asked to see the final product. Other times, children used Reaction functions on Zoom and chat to indicate their preferences during evaluation techniques (Likes, Dislikes, Design Ideas). Children would use text messages (-1, 0, +1) or stickers to react. Because some children chose not to use webcams, they could also choose to do other activities (e.g., play digital games) while also co-designing. Overall, the occurrence of cameras on or off appeared to be dependent on the choices of the child, the context, and the internet infrastructure.

Shorter sessions. The sessions had to be shortened because of the children's attention span and flow of the online activities. We were mindful that because we were online, we were already prolonging screen time duration throughout the day. Because co-design was not happening in local in-person settings and rooms, there was very little transition time physically. At the same time, because we shortened transition times between activities, we could not lengthen the activity any longer. Instead, we opted to shorten the co-design sessions by 15 - 30 minutes each sessions so that the pacing was faster and there was less of a chance to be bored. Because we shortened the times, we had to quickly figure out what was the most important parts of co-design for each session.

What technologies did not work. Not all technologies are the same for online co-design. Some technologies worked better than others. While adults might choose whiteboard programs like Miro, Mural, etc. children found these programs overwhelming and distracting. Even annotations on Zoom were difficult to use. Google Slides tended to be the default whiteboard of choice. However, children "trolled" each other and the adults by adding Pokemon stickers, deleting text, using Zoom annotation tools to draw everywhere, and overcrowding the slides.

Children's autonomy. As mentioned in the other teams, children could now choose whenever they wanted to come and go. In our team, they could go to the bathroom without permission, turn on/off their camera, choose to ignore the adults/children, decide when to leave/stay, play video games during the session, etc. We had a difficult time controlling the microphones when children were distracting. For instance, one child (Jack) kept whistling into the microphone the entire time (even when muted). When we muted him, he would unmute to whistle into the microphone constantly. Another issue about autonomy that would come up is when children would choose to come and when they would choose to leave. There was a sense of more unpredictability as children could come and go anytime. This made sessions somewhat unpredictable, often keeping the adults on their feet.

4.3.6. Surprises

Text messaging as very important. Text messaging in the co-design sessions became a very important staple for play and autonomy. Children frequently "trolled" each other on the text. Although we monitored the chat messages in Zoom, the children chose to be very playful on the messaging side. They posted frequent emojis, gibberish, and random statements. We decided not to disable chat (as many schools had done) because we wanted children to enjoy themselves with us. Although distracting, text messaging each other became a way for bonding and relationships to be formed. We eventually

(a) Building a fort with both physical and virtual materials

(b) Line Judging [43], but using objects of red (dislike), yellow (neutral), and green (like) to vote

(c) Creating a spaceship with both physical and virtual materials, and children's faces inserted into the scene

Figure 4: Adapting physical co-design techniques [43] into online spaces

learned that even in an online space, children needed time to learn to break rules and act like children. Text messaging was also quite necessary for when the internet connection was slow or children's microphones were not working. We had to rely on texting as a way to communicate well with the children. This meant that ideas sometimes had to take time to be presented and not always instantaneously via video-conferencing.

Close group dynamics over video and audio As mentioned in the other teams, we were able to capture close group dynamics that were never done. For the first time in our history, we were able to record very clear audio of video of group dynamics. In prior in-person work [44], we had a single camera capturing all the data. We chose a single camera because multiple cameras were very difficult to manage in a group of children in a small room. Instead, with Zoom recording, we could capture very specific adult/child interactions along with automated transcription. Even if the children had cameras off, capturing the audio clearly helped us to understand some of the group dynamics and collaboration. We plan to study specific adult/child interactions now with this data that we could not have done before.

Children really wanted to participate. Despite the pandemic, and some loss of children because of the difficulties of online interactions, the majority of children stayed with us throughout the year. They came back frequently and repeatedly. A number of children even came early while the adults were setting up. The low child-to-adult ratio helped facilitate needed relationship development.

5. Discussion

The research question that guided our individual and collective reflections was to better understand the experiences of online cooperative inquiry, or DPD with children. What we realized as we reflected upon and analyzed our past experiences was that our findings also help us to imagine the future of co-design with children, whether online, in-person, or in hybrid contexts. Thus, we divide our discussion into two sections:

- one that compares and contrasts our reflective experiences over the past 18-months (section 5.1), and
- a framework that looks toward a diverse future of multi-dimensional co-design contexts (section 5.2).

5.1. Compare and Contrast Themes and Discussion

As indicated in Section 3, we examined each case study reflection and held subsequent collaborative discussions to identify themes of similarities and differences among the design teams. For example, there were many common surprises and challenges that we encountered including tensions in adult-child power dynamics, a higher than expected interest in textual communication, an expanded sense of boundaries in our design spaces, and variations in the ratio of physical versus digital design materials/tools used.

5.1.1. Logistics - Technological Tensions

Some of the logistical commonalities included important documentation processes like a shared agenda and notes document (all teams), as well as minor structural changes such as shorter sessions and fewer design activities (e.g., Kidsteam Boise and Kidsteam UW). While Kidsteam Maryland used the same 90 minute sessions, they recognized that they had less design time and utilized more of that time for social interaction than they had during their face-to-face sessions. Kidsteam UW indicated that one of the reasons for shorter sessions was to purposefully not have children on screens for too long (in addition to their school) and allow team members to spend some time outdoors. While previous literature has called for more time to be allocated to online co-design sessions [19, 16, 3], the three teams either shortened their sessions or reconfigured the original 90 minute sessions they conducted in-person. Another common observation (and surprise) was that children used text/chat messaging more than anticipated. Similarly, Antle and Frauenberger previously noted that children could use the private chat functions with facilitators in order to express themselves [24]. In addition, we observed that children often used the chat feature to publicly or privately chat with other children, as well as the entire team. Additionally, we observed tensions related to accessibility and boundaries as discussed more in the following paragraphs.

Tensions related to accessibility: Equitable broadband technology. Opting to work with existing tech-

nology configurations at home (Kidsteam Maryland and Kidsteam UW) gave us insight into the diversity of systems and broadband connectivity available to the children and families with whom we worked. Although Kidsteam Boise attempted to use a common technology, broadband access still was a limiting factor and sometimes children utilized different platforms to connect (e.g., school-provided or home computers). Rather than depending on a physical lab setting common to all co-designers, we had to navigate multiple technology use contexts. Adults coordinated to test multiple browsers and systems prior to design sessions more than we had for face-to-face settings. Team participants ranged from rural, to suburban, to urban, yet all faced similar (at least occasional) issues of slower broadband that impeded their participation. We celebrated early moments when children could use school-provided laptops to connect rather than more limited mobile devices, or when they successfully moved in and out of breakout rooms with mobile devices without dropping offline. We became attuned to technology challenges that our child partners would face in a formal online school setting as well as in co-design sessions. It is one thing to be aware of the statistics for technology and broadband disparity in the communities surrounding our universities and quite another to grapple with them directly while trying to enact a co-design approach founded on equal partnerships. Maintaining enthusiasm, patience, and creative trouble-shooting are typical social characteristics of any intergenerational technology co-design team. Modeling and foregrounding these characteristics was even more critical in the face of crackling microphones, powering through multiple, frustrating disconnects and reconnects, or juggling multiple systems in one session.

Pushing boundaries of technology use. Many platforms, due to reasonable regulatory measures (e.g., Children's Online Privacy Protection Rule [COPPA] and General Data Protection Regulation [GDPR]), limit what children are able to do online. Each team took measures to ensure children's privacy and access. Some of the technologies experimented with in order to increase engagement included setting up private Discord servers or even Facebook Messenger. While parental consent was sought before exploring such items, we observed that there is a tension that exists when seeking to utilize technology to meaningfully interact with a co-design team and making sure all team participants are safe and their information remains private. Even the use of a shared note space (e.g., a Google Document) requires attention and care as to how it is shared amongst team members.

5.1.2. Tensions in Adult-Child Power Dynamics

We found that tensions and variability in power dynamics are more pronounced in online settings than in-person. In some cases, when technology issues arise (e.g., connectivity, interaction challenges), the balance of power is skewed toward the adults. Constantin et al. noted how DPD introduces power imbalances through a potential increase in intervention and reliance on facilitators and even parents [2]. Despite our efforts to afford children the same autonomy online as in-person, technical challenges required adults to take on more traditional adult-child power relations, acting as guides and facilitators.

In contrast, because children were in familiar physical settings while mediating their personal co-design interactions remotely, they gained more leverage to determine how they wanted to participate. The power dynamic often became more balanced, with children being able to choose more how and when they wanted to participate. Essentially, children had more control to participate as they liked in online design sessions. For instance, they might step away to take care of a pet or take a "bio-break" without asking for permission; they might play with a toy or scooter around the room while they chat with their teammates on their own time. In online collaboration, children contributed more at their own pace, making their own choices in how they participate. They could also choose to leave the virtual breakout rooms when they needed a break. When children "disappeared" from Zoom, we found that they either left on their own or technical difficulties took place.

5.1.3. Blurring of Boundaries

The diversity of physical contexts from – and through – which all team members connected during the pandemic has blurred the boundaries of interaction. These shifting boundaries was a *common* theme across all three cases: by connecting across a network, we not only expanded the view into our co-designers' lives and homes, but also enacted these perspectives through a technology-mediated, technology-constrained lens. Team members got a peek at children's lives at home, and they also got to see adults' homes. This was another opportunity to reduce power structures between children and adults. All teams experienced children bringing aspects of their lives into the cameras. For example, we saw how children play in their homes: they jump on trampolines, scooter around their living rooms, step out of the shower, and attend cello lessons. We encountered children's parents in a different setting, at home, rather than interacting with them via phone calls, emails, and text messages, or when dropping and picking up their

children. With online co-design, we sometimes interacted with parents during the sessions. Initially, the ability to show adults what is happening in their homes was exciting for the children. They enjoyed "show-and-tell" in front of the camera, showing off their pets, family members, toys, and rooms. Later, it became exhausting, as they had to attend all of their everyday activities online (school, playdates, etc.).

Additionally, this portal introduced other negative things that occasionally required adult facilitation to mute or turn off a camera in rare occurrences such as yelling in the background, inappropriate language heard in the background, or even a child who tried to join wearing a towel after just showering. Over time, children seemed less enthusiastic about turning on their cameras during sessions as they were exhausted from long hours spent in front of the screens or they sought more privacy, hoping to gain back some of the boundaries that allowed them to differentiate between home and other settings. Online co-design has been previously observed to give children more independence and privacy [2]. We agree that online co-design can give children more independence and control over their participation. Likewise, children can choose to either keep their cameras on or off for privacy. One must be mindful, however, of the potential blurring of boundaries and children's desire to maintain or reclaim their boundaries.

5.1.4. *Paper-based Low-Tech Prototyping vs. Digital Tools.*

Each team varied the ratios and types of physical, digital, and hybrid materials used as we negotiated technology-mediated design sessions. This variation afforded different levels of interaction and collaboration as we tried to rethink our design techniques. Paper-based PD approaches have been previously viewed as inefficient when working with widely distributed partners [7]. However, Kidsteam Boise continued emphasizing low fidelity techniques (e.g., "bags of stuff", big paper, and sticky notes), affording children opportunities to co-design with materials familiar to them as well as to stay active and "hands-on" as they designed. Kidsteam Maryland focused more on digital tools, aiming to gather the children through avatar "proxies" in the same virtual space (e.g., KumoSpace, Mozilla Hubs) or having them gather around the same artifact (e.g., Jamboard and Miro whiteboarding tools). Adults supported a sense of shared, co-mediated space by sharing their screens, enabling children to follow along, especially when connectivity or audio issues affected their interaction levels. Collaborating through avatars in virtual spaces afforded the children an embodied experience that served as effective proxies for in-person design sessions. Kidsteam UW combined digital tools and physical ones, mailed arts and crafts to children, and limited the design process to include only a shared board and the Zoom conferencing platform. Limiting the digital tools focused the children's attention on the design and less so on the technology. Using tangible means (e.g., arts and crafts) or digital embodied experiences (e.g., avatars) demonstrate different approaches that are still aligned with longstanding guiding principles of embodied cognition and social constructionism [45], whether online or offline [46]. In addition, the ability to "tinker" and play with physical artifacts or playfully embodied digital avatars, empowered children to participate actively in the design process, despite remote access and physical separation. These interactions also echo established values and activities that support children's learning and play (e.g., [45], [47]).

5.1.5. *Design Session Introduction, Outputs, and Boundary Objects*

In transitioning to online co-design, teams noted that design problem introductions needed more focus and could not be as abstract as in face-to-face settings where it seemed easier to co-construct and refine the problem with multiple small groups working on the same problem in the same room. Transitioning online also influenced the types of outputs created and boundary objects employed throughout the sessions. Boundary objects are elements (e.g., artifacts, concepts, processes) that simultaneously allow for multiple interpretations by diverse stakeholders who have differing worldviews and also promote cross-communication [37, 38]. For instance, a park map may simultaneously highlight places to play for children, reveal natural habitats important to scientists, or raise the risk of children getting lost to parents, all while maintaining the defining features of a map that can be shared and discussed by all of these stakeholders. For example, Kidsteam Maryland oftentimes used digital whiteboards both as a boundary object around which interaction was focused [37] as well as a shared output for the team, which differed from designing prototypes in person. Recent work has found that sustainability policies can serve as boundary objects that help a variety of citizens with differing worldviews – urban planners, policy experts, and everyday citizens – communicate and collaborate during difficult transitions [39]. Similarly, we often noticed that our shared view of the *same* digital whiteboard promoted dialogue and turn-taking amongst children (e.g., older/younger) and between children and adults in more

collaborative ways than when sub-groups designed in-person using separate prototyping materials. Additionally, Kidsteam UW gravitated to projects that could be most feasibly done online. Kidsteam Boise also gravitated to projects and design topics that were more readily addressed in an online format, but still employed physical prototypes (e.g. "bags-of-stuff", big paper, and sticky notes) for both design process and artifact. Kidsteam Boise often shared a screen with the summary of the big ideas that had been consolidated in the shared notes area (i.e., Google Docs) shared among adult facilitators at the end of sessions as a final validation and confirmation of the design outputs for that session.

5.1.6. Engagement & Mixed-Presence Collaboration

It was hard to gauge the engagement of some children when they had cameras off and sometimes did not respond to audio prompts. This extends Murai et al.'s finding that it can be difficult to recognize disengagement when children's cameras are turned off and non-verbal cues cannot be picked up [25]. While we anticipated changes to the collaboration, we noticed particularly that the lack of co-presence made it harder to collaborate. This is a common issue in the computer-supported cooperative work field. Presence disparity coined by Tang et al. refers to the tendency of co-present collaborators to interact more than with remote team members [48]. While a mixed presence or hybrid approach to co-design is possible, there are challenges that need to be addressed [49, 50]. McEwan et al. [50] proposes a framework to draw upon related work in distributed and collocated collaboration, but they assume that in most cases the shared workspace is digital. In Kidsteam Boise, while digital artifacts were used, the collaboration was challenging for children and many either used their own virtual space (e.g., their own slide within a shared online presentation platform), or they used physical arts and crafts supplies which were not shared as they were not collocated.

5.2. Future of Cooperative Inquiry and Online Co-Design

As a result of these three case studies of online co-design implementations, we now consider Guha, Druin, and Fails' reflections of the past and guidelines for the future of cooperative inquiry [23]. Just over a decade after cooperative inquiry was first implemented, Guha et al. reflected upon important trends in technology that would affect design partnerships for the future. Such predictive trends include:

Figure 5: Druin's [26] design partnership (A) is reconsidered with more dimension and depth from our four tensions, as conceptualized by a sphere (B).

- the shrinking world and how children would collaborate with others far away;
- the growth and importance of mobile technologies for co-design and how children will be switching between physical and digital worlds;
- the importance of social computing and the need for social interactions both online and physically together; and
- how searching technologies would affect how children find information for co-design.

Since Guha et al.'s [23] almost a decade ago, we ourselves consider how life has changed, particularly over the events of 2020 including the global COVID-19 pandemic, which pushed us all into areas we did not anticipate. In the spirit of Guha et al.'s predictive vision of design partnerships in the future, we also take a moment to reflect on how the years 2020 to 2021 have changed our collective vision of cooperative inquiry [26, 10]. We observe and consider four dimensions that all designers who co-design closely with children will face in the near future. We conceptualize our dimensions in relation to Druin's [26] model of children users, testers, informants, and design partners. Figure 5 demonstrates the depth of these tensions provide in relationship to the role of child design partners.

Druin's original four dimensions ([26]) focus only on the role of the child, as represented by a singular plane (concentric circles). However, we expand our understanding of these roles and their relationships with additional contextual dimensions. The sphere represents a range of possible contextual planes that influence the user, tester, informant, and design partner model. By examining contextual factors like scale vs. intimacy, freedom and autonomy, mediation through technology, and meeting children's physical interaction needs, we gain additional facets for envisioning how co-design sessions, particularly those online, are influenced by these tensions. Other models from the CCI community that consider child partnerships and roles (e.g., [51, 52]) could also benefit from these contextual dimensions when considering DPD.

5.2.1. Scale (Broader Inclusion) vs. Intimacy of Design

From our time with COVID-19, all three teams have now examined how diversity, equity, and inclusion play a role in how children participate in DPD. If online tech-

nologies mediate how co-design is enacted with children, we are no longer limited as much to physical boundaries and transportation logistics. We can recruit children down the street from the university, as well as anywhere out the world [16]. Kidsteam UW had adult partners logging in from Taiwan, Korea, Chicago, New York, Colorado, and other faraway places. Virtually, we could host more children and adults in the breakout rooms and online space. Despite the potential broadening of participation that online co-design might enable, building trusted relationships and rapport requires a level of intimacy that is likely difficult to achieve as co-design sessions "scale up" [2] How do we balance increased inclusion with the need for intimacy? Even on a basic, practical level, we must recognize that the more co-designers who can participate, the more time is needed to share co-design ideas. All three teams struggled to strike a balance between broadly inclusive yet intimate, relationship- and rapport-building online collaboration. Indeed, some of us have never even met face-to-face with our adult and child design partners. These competing issues surface a tension between scaling up to include all children, while also developing techniques, stances, and facilitation that engender trusted rapport and relationships. All of us are now asking a crucial question: where is the sweet spot between expansion and relationship building?

5.2.2. *Shifting Roles as Mediated Through Technology*

As Guha et al. noted in 2013 [23], the changing world of technology ultimately influences how cooperative inquiry is enacted and practiced. This is clear as we have all endured the COVID-19 pandemic in both quarantine isolation and more interaction through technology than we have ever had before. For instance, families all across the world have had to reconsider what screen time is and how technology usage played a role in their family engagement during the pandemic [53, 54]. Schools and institutions transitioned to online settings, whether they wanted to or not, and in some cases, whether they even could make the transition, given the number of families who remain without or with minimal online access [21, 55]. In at least one case, online co-design sessions were able to restart even before local schools were back in session.

Similarly, we examine the initial design roles formulated by Druin [26]: user, tester, informant, and design partner. For all teams in this study, co-designing technologies for and with children in multi-faceted roles was the primary goal; post-pandemic, child interactions in these roles are now mediated *through* online technologies as the *means* of design. Druin [26] focused on how children assume different roles at different points in the design cycle, along with shifting child-adult power dynamics, which enabled a range of design outcomes. Our transition to fully online co-design has revealed new dimensions for our roles, relationships, and collaborative interactions.

For example, in the role of users, how do we observe children directly when the pandemic forced us to remain physically apart? To support children's roles as testers, we had to creatively consider how remote technologies mediated children's online views of our prototypes. How might the online layer of interaction expose prototype features and capabilities to children online? As for informants, how can we develop the necessary dialogue to have children consult on a project? Lee et al. [3] noted that for design partnerships with children, the logistics of the design, the contexts and setting, and the interpretations of the partners are all influenced by technology usage. We now pose the question: How do we conceptualize the changing roles that children play in technology design [26] when our interactions are mediated through yet another layer of technology (i.e., remote presence)?

5.2.3. *Freedom and Autonomy*

As we noted in the findings, the children all developed new ways to interact online with more autonomy. They could make more choices and decisions than any time we had encountered. However, as children gained more autonomy through technological prowess, were they also losing autonomy? The tyranny of freedom is an argument that self-determination and autonomy can itself become excessive and lead to less, not more, freedom [56]. While design partnerships are a balance between adult and children's relationships, choices, and interaction [44], we also noted that more autonomy was a double-edged sword. As children could now choose to turn their cameras and mics on/off, their partnership with adults was also affected. At the same time, there were benefits to children making their own choices and decisions. This aligns with the situation-based actions observed by Kensing and Greenbaum where working within the context of co-designers changes the mutual learning and tools and techniques that need to be utilized [57]. We acknowledge that the power dynamic differed and while it gave some additional autonomy to children, in some instances it hampered the overall collaboration as it was more difficult for cross-collaborations to occur when people were not present.

Many of the children in all three teams came because they wanted to, not because they were obligated to. However, a few children left the design teams be-

cause they no longer enjoyed the online setting. In summary, as we consider the post-pandemic design partnership, we need to more closely examine the choices and decisions children have, both in the physical and digital spaces – including both "on task" design activities and "off task" (or even "rule breaking") activities.

The learning that occurred during online design sessions could lead to some practices that could benefit face-to-face or in-person design sessions as well. The additional awareness of children to exert their power and to take breaks should heighten facilitators' awareness of the needs of children to do so even in an in-person design session.

5.2.4. Physicality: Meeting Physical Interaction Needs

Physicality, and close collaboration is an important part of face-to-face co-design for children and adults to build rapport and trust. Requirements to maintain social distancing with unvaccinated children would make this face-to-face interaction challenging, and perhaps less efficient than what was achieved with the teams in online collaboration, where they can work on shared boards and navigate through virtual reality spaces. In addition, social norms that children and adult design partners adopted would need to be modified for in-person co-design that requires social distancing. Considering social distancing requirements might require modifying the design techniques according to new in-person co-design constraints.

Similarly, it was impossible not to consider physicality in terms of co-design and learning. Embodied cognition notes that people's experiences, learning, and interactions are all deeply rooted in the physical body and world [46]. As we transitioned to online worlds, it was still important to have children use physical materials for design, drop off physical items for design, and even consider how the physical rooms and contexts in which children and adults collaborated became design spaces. Therefore, even in the roles of children in cooperative inquiry, we need to ask how does variation in embodiment, physicality, and online technology influence the roles?

6. Conclusion

In this reflection of online co-design in 2020 and 2021, we have examined three different case studies of intergenerational design teams of children and adults as they cope, adjust, innovate, adapt, and pursue what it means to be design partners. As we attempt to return to the "normalcy" of in-person sessions, it is important not to just revert to what pre-COVID times meant for co-design. We have shown both the highlights and challenges of cooperative inquiry during the pandemic as a hybrid and fully online team. Through this reflection, we believe the future of co-design post-COVID-19 can push the boundaries of pre-pandemic co-design by purposefully considering the dimensions of scalability/intimacy, technological influence, freedom and autonomy, and physicality in co-design. While we focus on the roles of children, we believe that design researchers can examine and reflect upon the dimensions and depth we have expanded upon Druin's [10, 26] roles in Cooperative Inquiry. More research post-COVID-19 will be needed to understand more clearly how these dimensions influence and shape co-design in the years to come. The case studies presented herein along with the discussion contribute to a deeper understanding of online co-design and how it will shape that future research.

7. Selection and Participation of Children

Children who participate in the design teams are recruited locally via protocols approved by institutional review boards. All children and their parents are provided with simple and clear information regarding what participation on the co-design team entails including an expectation that children will participate in design sessions twice a week (with an understanding that some conflicts may arise). Children are treated with great care, and in word and many small actions are encouraged to view themselves as and to act as full partners in the design process.

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Conflict of Interest

One author on this submission is also an editor of the special issue, so please route this through a different editor.