Brownies or Bags-of-Stuff? Domain Expertise in Cooperative Inquiry with Children

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ABSTRACT
Researchers often utilize the method of Participatory Design to work together with users to enhance technology. In particular, Cooperative Inquiry is a method of Participatory Design with children that involves full partnership between researchers and children. One important challenge designers face in creating learning technologies is that these technologies are often situated in specific activities and contexts. While children involved in these activities may have subject expertise (e.g., science inquiry process), they may not have design expertise (e.g., design aesthetics, usability). In contrast, children with design expertise may be familiar with how to design with researchers, but may not have subject expertise. Little is known about the distinction between child design and subject experts in Cooperative Inquiry. In this paper, we examine two cases – involving children with design expertise and those with subject expertise – to better understand the design process for both groups of children. The data from this study suggests that similarities do exist between the two cases, but that design and subject knowledge does play a significant role in how children co-design learning technologies.

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Life-relevant learning, co-design, children, learning technologies

1. INTRODUCTION
Designing technologies for children is no easy task. Children do not think like adults and have their own needs and preferences. Therefore, researchers have used *Participatory Design* (PD) as a method to enhance technology for children by designing with children. Children often play four roles in technology development: user, tester, informant, and design partner [9]. The current paper focuses on the most involved PD method of working together with children as design partners, known as *Cooperative Inquiry (CI)*. As a subset of PD, CI has been used for over a decade in the design of children's technologies. CI is a method that consists of adults and children working together as *design partners* on the iteration and elaboration of technology design. CI has been widely used as an effective approach for designing children's technologies [3, 8]. While the inclusion of children in the design of new technology is important, designing for domains in which they are not familiar can be challenging. The CI process enables children to develop expertise in the domain of design. For example, in our lab, we partner with children for one year or longer in CI. Over time, the child design partners develop knowledge of the CI processes, relationships with one another, and experience in the physical context. In essence, they become *design-domain experts*. In this paper, we simply refer to them as *design experts*.

Yet, even with design expertise, CI can be challenging when children do not have enough *subject-domain* expertise (or *subject expertise* for short). For example, our lab's design team once partnered with a non-profit organization to develop a web-interface to help children understand the American legislative process. Although we worked with an older subset of child design partners (ages 11–13), the children with design expertise had very little subject knowledge of civics and law. Much of our design time was therefore spent briefing the children on definitions and the legislative process. Although the older children had ideas about technology usability and interaction, the ideas they generated (e.g., a first-person shooter game) were not specific to the context of government legislation.

From this experience, we recognize that working only with design expert children could be limiting in CI. In particular, learning technologies, such as the legislative website, are often situated in specific physical contexts (e.g., classrooms), activities, and content knowledge. In these cases, child co-designers may need to spend time acclimating themselves to the practices, culture, relationships, and skills of the intended learning context. However, children who have spent more time developing subject expertise may be novices in the co-design process and face difficulties engaging in fruitful CI [11]. A second problem now becomes apparent; prior research has shown that CI is not always a simple process [9]. Like all good design partnerships, children need to learn how to design and feel comfortable designing with adults.

Although we know from prior research on Contextual Design [2] that expert designers and subject experts have different knowledge and perceptions, we do not yet know the degree of difference between children who are more familiar with CI and children who know more about a particular curriculum or program. This study

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seeks to better understand the role that design and subject expertise play in the design process of children's learning technologies. For the study, we examined two cases of child design partners from *Kidsteam* (design experts) and *Kitchen Chemistry* (subject experts). Each group of children engaged in the same design activities to support the development of *ScienceKit*, a mobile app for future use in Kitchen Chemistry [5], and these activities were compared. Our research questions for this study are:

1. What are the affordances and constraints of designing learning technologies with children with subject expertise?
2. What are the affordances and constraints of designing learning technologies with children with design expertise?
3. How can the results of designing with the two groups be combined to inform design practice that involves either group?

Specifically, we are focusing on the design of ScienceKit to help learners engage in science inquiry practices across school, home, afterschool, and other learning environments (Figure 1) [6]. ScienceKit will support specific inquiry practices such as developing questions and hypotheses, building investigations, making arguments, and using integrated and social media to capture and record data. CI is an important design approach in our efforts to develop technology that children are motivated to use across different settings. In the future, we envision children using ScienceKit in *Kitchen Chemistry*, an afterschool or summer camp program that supports the development of scientific inquiry skills through hands-on learning activities, such as making and perfecting dishes. The use of ScienceKit is therefore tied to the contextual activities of cooking and investigation development.

Figure 1. ScienceKit in Kitchen Chemistry. The mobile app is situated in the cooking and science activities.

2. DESIGNING WITH CONTEXT IN MIND

In discussing the importance of designing technologies with children's learning context in mind, we first review the use of activity theory as an approach to HCI design. Next, we examine the connection between context and user-centered design. Finally, we make the case for CI as a way to understand context in children's design of learning technologies

Studying user contexts informs our understanding of the relationship between individuals, artifacts, and social groups [16] and is a key consideration for the effective design of technologies. Contextual (or environmental) awareness helps designers to understand how existing technologies fit into the spaces users inhabit. This awareness of the activities users undertake, as well as how to design technologies that will fit better within those spaces and activities is important [17]. Taking context seriously in our designs involves examining the complex interactions of particular individuals at specific times and situations.

In Nardi's [16] analysis of existing psychosocial approaches to context and their applicability for HCI design studies, she concluded that activity theory [14] offered the richest model for design researchers, largely due to its integrated emphasis on user motivation and perspective. For example, a desktop computer may be a stable object in a family home, and an Internet search (the situation) may involve similar actions by each family member (e.g., open browser, type search text). However, each family member's activity may be different based on the type of search query they want to initiate (e.g., sports, recipes, toys), and the type of experience and skills they have to execute the query (e.g., children may prefer oral input over typing). Activity theory accounts for all of these contextual elements: subject (family member), object/artifact (browser), and the activity that is mediated between the subject and object (search). In activity theory, context is both internal (e.g., goals, values) and external (e.g., movement, objects, interactions). Each element cannot be studied in isolation. Just as sodium and chloride cannot not be pulled apart to try to understand salt, the subject, objects, and the mediating activity cannot be pulled apart without losing some aspect of a holistic, contextual flavor [14].

We have adopted activity theory as our design-based approach to understanding context. Specifically, we draw on four methodological implications for HCI design studies from Nardi's [16] analysis of activity theory:

1. A research time frame long enough to understand users' objects.
2. Attention to broad patterns of activity rather than episodic fragments.
3. The use of a variety of data collection techniques.
4. A commitment to understanding things from users' points of view.

All the context-based models that Nardi [16] analyzed to support HCI design studies, including her recommendations above, highlight the importance of understanding the user's point of view. However, an issue not covered in the models, but significant for the effectiveness of them, is how users can voice their own opinions on their contexts and technology interactions. All of the context-based frameworks that Nardi [16] surveyed situate the design researcher as an objective, outside observer looking inward at the user, the activity, social interaction, and technology use. In effect, the user often does not have a chance to make *direct* inputs to the design of the technology.

To rectify this imbalance between attending to users without directly including users, methods such as *Contextual Design* [2] have been developed to involve users more directly in the design of new technologies. In Contextual Design [2], designers follow Contextual Inquiry, which involves interviewing and observing users in their work environments to develop an understanding of their needs and work models, then prototyping interfaces from these data for testing with users. Similarly, *Bonded Design* [13] includes children in the design process as collaborators in context. However, because Bonded Design occurs only within a few focused weeks, this limits the extent to which full, equal partnerships can occur. CI, which involves the most direct, equal partnership with children, can enhance our understanding of the importance of designing learning technologies with context in mind. Thus, our investigative goal is to design with both subject and design expert children to better understand the role that activity and domain play in learning technologies design.

Nardi's [16] four methodological guidelines from activity theory informed our approach within CI. First, to understand users' relation to objects over a longer time frame, design processes with users had to be expansive and not isolated to a single session. Second, in order to attend to broad patterns of activity, we could not examine episodic design sessions in isolation. CI enables a broad, multiple session view, as researchers and children work together over time to realize a full partnership. Third, we needed to collect diverse and complementary information, using different co-design techniques, to achieve diversity in data collected. Within CI, multiple forms of data are generated naturally, and researchers and children are acclimated to producing analyzable data. Finally, and most importantly, a commitment to understanding the user's point of view is the foundation for CI and was our means to determine how subject and design expert children each conceptualized the co-design of ScienceKit.

3. METHODS

For this study, we implemented the standards of a comparative case study [21]. We wanted to understand and explore the differences between children as design and subject experts. Therefore, the two cases we compare are two groups of children participating in similar co-design activities across different settings and experiences. Our case study aims to develop analytical generalizations, that is, to generalize a particular set of findings to a broader theory of using CI with all children when developing a single app [21].

3.1 Participant Group Cases

We selected two groups of children – Kidsteam designers and Kitchen Chemistry participants – as the two cases for examination. In this paper, we use the term "KC" to denote the group of co-designers from Kitchen Chemistry. We selected these two cases because of each group's distinctive domain expertise.

The Kidsteam design group represents our study's 'design experts'. Kidsteam is an out-of-school program that focuses on co-designing technology for children, with children. Kidsteam members include children (7-11 years old) and adult design researchers. The design team begins during the summer in a two-week day camp and then meets twice a week after school during the following school year. Throughout the year, the team develops, evaluates, and co-designs new technologies for children. They are regularly exposed to co-design techniques and work on multiple projects with various outside institutions over an extended period of time. Because Kidsteam members meet consistently to co-design, the participants develop close relationships with each other during design activities. These close relationships are also encouraged through unstructured activities, such as playing games and snack time. Kidsteam is an ideal case for the design of ScienceKit because their design experience enables them to quickly co-design and iterate on ideas.

The second design group – the 'subject experts' in this study – was composed of KC children and adults who participated in the Kitchen Chemistry program. To better understand the design of technologies for learning activities, we are developing ScienceKit together with Kitchen Chemistry, a life-relevant learning environment to support learners' understanding of the relevance that scientific thinking, processes, and experimentation can have in everyday life. This instantiation of Kitchen Chemistry was enacted as an all day, one-week summer program and as a twelve-week, once a week afterschool program in the spring. Two different sets of children participated in the summer and afterschool program. Nine children (8-13 years old) participated in the summer and six children (8-11 years old) in the afterschool program. The child participants are from different public and private schools from the local area. Five adult researchers acted as facilitators throughout both periods.

We developed Kitchen Chemistry with five aspects in mind for science inquiry [5]. First, participants partner together with adult *facilitators* to explore science through cooking. Through this guidance, learners engage in *semi-structured activities* that help familiarize them with cooking and science practices. These activities ultimately prepare the participants for flexible exploratory activities called *Choice Days,* in which learners have the opportunity to use what they have learned to prepare a food investigation of their choice. Embedded in both the semi-structured activities and Choice Days are *whole-group discussions* that raise learners' awareness of both the causal mechanisms of observed phenomena and the relevance of science knowledge in their everyday lives. Finally, participants use *mobile technologies* to help them design, document, and share their investigations. In particular, children used three apps in Kitchen Chemistry. SINQ [1] is a prototype social media tool to enhance science inquiry. StoryKit [3] is a mobile storytelling app. Zydeco [4] is a guided-inquiry app that allows learners to use integrated media to record and tag data.

3.2 Design Sessions

In three design sessions spanning approximately one year, we investigated how each group of children co-designed ScienceKit. Our goal is to develop ScienceKit, a suite of communication, data collection, analysis, and sharing tools all built into a single app. For these sessions, ScienceKit was still in the very early phases of development. We examined three design sessions (see Table 1 for findings summary and setup) with each of the groups to better understand the range of ideas for technology development. Data collection occurred during six co-design sessions – three similar sessions with each group of children. The three design sessions used different co-design techniques to elicit feedback about design ideas for ScienceKit [10]. The three sessions were:

Bags-of-Stuff: This is a low-tech prototyping technique [7] (Figure 2). Small groups of co-designers create models of new technologies using bags containing pre-determined household art supplies (e.g., construction paper, glue). The goal of this design session was to generate ideas for learning technologies that could be used in Kitchen Chemistry. The children and adults worked in small groups, each consisting of one to three child partners and at least one adult. Each group presented their designs to the full team, while someone recorded the "big ideas" on a large white board ("big ideas" are those that are repeated among the groups and receive the most attention in the whole group discussion).

Stickies: On small pieces of paper with mild adhesives (sticky notes), children recorded one idea per note of their likes, dislikes, and design ideas about using mobile apps in science learning contexts [7]. An adult designer organized the notes into clusters of similar themes (Figure 3) because of the large number of notes that need organization [22]. In a whole group discussion, these themes informed the outcomes of the session.

Layered Elaboration: In this session, children reviewed and iterated on a low-fidelity paper prototype of ScienceKit. The goal of Layered Elaboration [20] is to enable iterative design without destroying the original ideas. Designers add layers of overhead transparencies onto paper prototypes (Figure 4). Similar to the other sessions, the larger group was divided up into smaller teams. Each team was given a clipboard with the overhead transparency

on top of the prototype and used permanent markers to draw their ideas on the transparency. After a specified amount of time, the teams met together briefly to present their designs while an adult recorded the "big ideas." Then another transparency layer was added on top of previous ideas and the clipboards were exchanged with another team. In the next round, children continued to add more designs onto their transparency.

Figure 2. A sample low-tech prototype from "Bags-of-Stuff".

Figure 3. An example of "Sticky Notes" co-design technique.

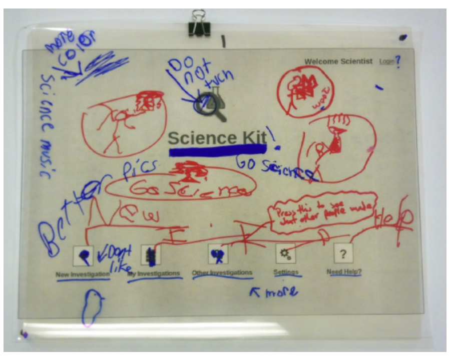

Figure 4. A "Layered Elaboration" sample.

3.3 Data Collection

Because each design session had a different goal pertaining to the stage of design of ScienceKit, different co-design activities needed to be used [19]. Each of the design sessions resulted in different artifacts for our evaluation, which included low-fidelity paper prototypes, short notes, and drawings. We also took photographs and recorded video for all sessions. After each design session we held debrief meetings to review the artifacts and feedback that was generated. We wrote up analytical memos from the raw data to further flesh out the concepts and emerging patterns. Two authors planned and facilitated all design sessions with Kitchen Chemistry and Kidsteam designers. The remaining authors also spent time participating in Kitchen Chemistry, either during the summer or afterschool sessions.

3.4 Analysis

To examine our data sets of low-tech prototypes, notes, design layers, and presentations, we used a grounded theory approach with constant comparative analysis [18] and observed emergent patterns that we interpreted as important in understanding the similarities and differences in co-design with subject and design child experts. Three of the authors individually applied an open coding on the artifacts and feedback from the design sessions. Each researcher examined the children's feedback and design artifacts, and coded them for specific themes pertaining to the design. For instance, we openly coded the feedback for aspects of usability, interaction, device specific features, and design ideas. In a collaborative axial coding session, the researchers compared and contrasted the open codes to identify the emerging themes from the respective design sessions. We developed codes regarding children's design desires for social interaction, customization, aesthetics, integrated media, tagging, and others. Using our analytical memos, photographs, and videos, we triangulated the data to make sure all pieces of evidence supported each other [15]. To establish validity, we presented each design session to three external reviewers not closely involved with the project to ensure that the comparison of the two cases was representative of the ideas and design process of the children. Once each case was developed, we conducted a cross case analysis [21] between the KC and Kidsteam cases to see what similarities and differences could be detected.

4. FINDINGS

In this section, we first describe the context and setup of the design activity as presented to each of the two groups of children. Next, we provide the findings of the artifacts generated from the design session through a comparison of the two cases. We compare each case for 1) similar design themes; 2) general similarities, but different implementation details; and 3) differences between the design themes. We then discuss each case by providing analysis and discussion of the findings. Table 1 shows the summary of our findings. In Section 5, the case discussions are used to examine the larger issues pertaining to design work with design or subject experts.

4.1 Design Session #1 – Bags-of-Stuff

4.1.1 Context and Setup

For the Kidsteam children, we ran the Bags-of-Stuff session in the spring school term prior to the first summer implementation of Kitchen Chemistry. At this point, each child in Kidsteam had already participated in co-design for several months. Eight children (four boys and four girls, 7-11 years old) from both private and public schools collaborated with ten adults (students and researchers). To get the children in the mindset of the project, we began the session in a whole group discussion, by asking the design partners, "what cooking questions do you have?" After the group discussion that followed, we asked the children to prototype a technology that would help them answer their cooking questions.

The KC design group's Bags-of-Stuff session occurred during the weeklong, summer program. Seven children (four girls, three boys, 9-13 years old) participated in both the program and the design session, together with five adult facilitators. From Monday to Thursday children engaged in the semi-structured activities of typical KC, developed cooking investigations, and shared their perspectives in whole group discussions. During this time, the children used StoryKit [3] and Zydeco [4] to capture data and share their results. On Friday, the KC participants engaged in a Bags-of-Stuff design session to develop a technology prototype they wanted to use to help them learn science through cooking. The KC children engaged in approximately 30 hours of the program, while Kidsteam children only spent 15 minutes thinking

about cooking. We chose not to use the same Kidsteam group discussion prompt because the KC children had been asking cooking questions throughout the whole week. Instead, we asked the KC children to design an improved technology for the Kitchen Chemistry program.

4.1.2 Comparative Findings

Similarities: From the Kidsteam and KC design sessions, we found four emergent themes pertaining to elements that are desired for our ScienceKit app.

Familiar interfaces: All the children developed low-tech prototypes reflecting the familiar interfaces of microwaves, iPads™, and Nintendo DS™. Drawing on online commercial devices, the design partners in both groups wanted to capture their experiences in photos and videos and have the ability to share their experiences with others.

Process displays: Displays that showed process were important. Both groups of partners prototyped technology that could display different processes involved in cooking and eating, such as technology that could take snapshots of what their food looks like as it cooks and what foods look like as it goes through the digestive system.

Guidance: Both groups asked for devices that could guide their cooking investigations. Several prototypes could help to make choices between ingredients or food characteristics. For example, the Kidsteam children designed a "taste chooser" to help them to select what ingredients they needed to get a particular flavor, and a tool to help select the particular temperatures that would produce the right texture in their foods.

Sensors: Both groups of children built external probes into their prototypes that could point directly to their foods to scan, record, and measure different variables and give information about that food, such as taste and temperature.

Similar, but different: Both groups came up with three similar themes; however, the details of the designs differed.

Mobility vs. Unobtrusiveness: Both groups wanted tools that could easily move and interact within the context of a kitchen science investigation. Most of the Kidsteam children developed prototypes that were specifically handheld (e.g., tablet, probes), but did not consider that their hands would be used in cooking tasks. One Kidsteam group did come up with a bracelet to wear, but the emphasis was that the bracelet would detect "mood" in cooking, not how it could be less obtrusive during cooking. In contrast, KC designers explicitly included unobtrusive ways for technology to help them conduct their investigations. KC children developed a prototype flying device and a remote that helped them to control the oven. Another KC group wanted voice activation that could help them multitask in the investigation.

Gamification: Both Kidsteam and KC designers tended to include some form of game into their prototypes. One Kidsteam group wanted a game in their prototype; however, this game had nothing to do with cooking or science investigations. In one KC group, the children focused the game in the Kitchen Chemistry context. They asked for a point system that would keep track of the number of investigations and recipes they were modifying or implementing. The more points a learner earned, the more tools and recipes they could unlock.

Social communities and interactions: Both groups of children wanted to communicate with others. However, the KC children expressed more details about sharing and collaboration. For Kidsteam, the children briefly mentioned that the portability of the device allows them to share their experience with others. In KC, some children wanted to be able to see what others were doing and what kinds of science investigations about food were being conducted. If the investigations seemed interesting, KC learners wanted to download and conduct the same explorations. The KC children also wanted to send messages to their parents and show them what investigations they were conducting. One participant wanted to post questions about investigations and food and have other learners interact with her on these inquiries.

Differences: One main difference between the Kidsteam and KC designs emerged.

References and information retrieval: KC learners included in their designs a means to retrieve information about the foods or ingredients they were working with. One group asked specifically for a scanner that could scan food and fetch information about it. Some groups wanted quick access to thousands of recipes they could try out and experiment with. This idea did not arise during the Kidsteam session.

4.1.3 Session Analysis and Discussion

Kidsteam and KC designers addressed similar design issues in the low fidelity prototypes. Kidsteam co-designers developed ideas that were broadly applicable, but did not focus in on the subtle aspects of the Kitchen Chemistry activities. Although we had introduced the idea of food investigations and science, the Kidsteam children were unable to conceptualize the specifics of context. For example, the Kidsteam prototypes did not acknowledge the difficulties of handling the mobile devices while cooking or the importance of references and information retrieval.

Participation in the Kitchen Chemistry environment did influence what the KC members thought was important for the prototypes. KC participants engaged collaboratively in a full week of cooking activities prior to design work. Proposing a tool that allows learners to communicate with their friends and share their activities may reflect the relationships and interactions they were developing in Kitchen Chemistry. These subject experts were constantly asking questions and making inquiries into the investigation. This desire for information resulted in the design of a reference tool that could help them retrieve information to satiate their curiosity. Having reference information available in-situ within the activity might also serve as a means to further develop engagement, interest, guidance, and inquiry investigations. The need for tools that can easily adapt to the cooking task (e.g., flying cooking robots) is further evidence that immersion in Kitchen Chemistry activities influenced the designs. During the cooking and science experiments learners often dropped the iPads™ and fumbled with the kitchen tools, which contributed to a lot of spills and messes. Although KC members were not as experienced in co-design as Kidsteam members, they came up with similar themes based on contextual familiarity with the Kitchen Chemistry environment. One possible reason for this finding is that the Bags-of-Stuff technique has a low barrier to entry [19] and most children seem comfortable with the technique.

4.2 Design Session #2 – Stickies

4.2.1 Context and Setup

In Design Session #2, the children reviewed two science inquiry technologies – Zydeco [4] and StoryKit [3] – using Stickies [7] (Figure 3). These two apps were integrated into the Kitchen Chemistry environment to evaluate what considerations are needed to create a technology that more fully supports learners approach to science inquiry. Using Stickies, the children were

able to provide feedback about the utility, interaction, usability, and aesthetics of the apps in a cooking investigation scenario.

We conducted two different Stickies sessions each with the design partners. First, the Kidsteam sessions independently reviewed StoryKit and Zydeco. For Kidsteam, we ran the Stickies session for StoryKit in the summer. Eight children participated (five girls and three boys, 7-11 years old). Prior to this Stickies session, the Kidsteam children baked chocolate brownies and used StoryKit to capture their experiences. We conducted a second Stickies session in the following winter to review Zydeco separately. The same Kidsteam children from the summer participated, except for one child. In this review session, the children observed characteristics of baked goods (e.g., textures, taste) and used Zydeco to record their observations. Second, during the summer implementation of Kitchen Chemistry, we conducted Stickies sessions to evaluate StoryKit (day two) and Zydeco (day five) with the KC children. This group of KC children was the same group who participated in the Bags-of-Stuff session on day five (four girls, three boys, 9-13 years old). Prior to both Stickies sessions, the KC children had engaged in cooking activities with the apps.

4.2.2 Comparative Findings

Similarities: We found two main themes that were similar between the groups.

Child-friendly fun: For StoryKit, both groups liked the integrated media (e.g., audio, photos, paintings) and wanted video integration. In Zydeco, both sets of children wanted tagging to be like a game. While both sets of children liked tagging data, they thought that the interface could be more child-friendly.

Technical details: In StoryKit, both groups complained about the difficulty of resizing photos and thought interaction with the buttons could be easier. Everybody liked to record audio in Zydeco, but both groups expressed a desire for speech-to-text and felt that 60-second audio recordings were too short.

Similar, but different: The groups came up with three similar general themes, but emphasized different details.

Customization and control: Both co-design teams wanted more control and customization in StoryKit, but the control and customization had different foci. Kidsteam co-designers wanted more control over aesthetics. For example, they asked for more colors for painting, the ability to change fonts and backgrounds for stories, and more brush sizes for painting. The KC children focused on interaction. They pointed out that moving the drawings was hard, creating new pages was a challenge, and page numbers should be inserted by default. The KC children wanted more control over the movement and layout of the media.

Story-like features in Zydeco: Both groups of children wanted story-like features in Zydeco. However, KC children were notably more emphatic about this. KC children also asked for authorship attribution, that is, an indication of who made what contribution.

Tagging issues: Both groups liked tagging data, but Kidsteam children were more outspoken about interaction design issues with tagging. The Kidsteam children spent more time recording design ideas about how the tagging could be implemented. The ideas included moving tags around the photo, auto tagging, classifying tags based on the five human senses, and separating audio from textual tags. Children in KC tended to express likes and dislikes more than design ideas, for example, “like: tagging is fun” and “dislike: I wish there was a way to put more tags.” One KC child expressed a need for spell check support for tags. Kidsteam children also expressed more ideas about usability in Zydeco, such as how to start working in Zydeco, how to complete a tag, and what steps and functions they were supposed to engage in.

Differences: Profound differences were present in the evaluation of StoryKit.

Social collaboration and organization: When using StoryKit, Kidsteam co-designers enjoyed the sociability of passing the iPad around and taking turns contributing to a story. Kidsteam designers stated that they enjoyed social collaboration using StoryKit and said the stories needed to be shared more. Kidsteam children wanted organizational features such as grids and reminders in StoryKit. They also asked for ways for the technology to inspire new ideas (e.g., an idea button). While important to Kidsteam, these features were not mentioned by the KC children.

Multitasking: Instead, for StoryKit, the KC children described multitasking as important. They needed the technology to help them do multiple things at once, such as record the story and cook at the same time. Their suggestions included a stand that would allow them to record themselves while cooking. The KC designers did not emphasize idea generation, organizational tools, or social collaboration.

4.2.3 Session Analysis and Discussion

Distinctions between design knowledge and subject knowledge became more prevalent in the Stickies activity. The Kidsteam children gave more opinions when evaluating the interaction, design, and usability of the apps. While both sets of children had opinions on tagging, Kidsteam co-designers generated more new ideas about tagging, particularly how to tag, how the tags should look, and what new features tags could include. Kidsteam children also considered more navigational issues, such as how to start and end Zydeco. They displayed more concern about colors, fonts, and overall child-friendly design. Such *interaction in context* knowledge is often developed most effectively when users work closely with other users and designers [12]. The KC group emphasized certain features, while overlooking others. Working under the guidance of facilitators, the KC children could already generate science-based questions and organize their investigations. The fact that Kidsteam did not use StoryKit and Zydeco as much in a food investigation context may have encouraged their need for certain tacit features.

Practical constraints regarding the design sessions may have played a role in how the children generated their design ideas. The KC group reviewed StoryKit and Zydeco continuously, while Kidsteam examined the apps in two different sessions, months apart. This may have influenced what the children emphasized in their review. We noticed that the KC children focused a great deal on story-like features and ways to identify contributors in Zydeco; these are prominent features of StoryKit, and were not emphasized in Kidsteam. Here, the KC children’s greater experience with StoryKit may have influenced what they found missing in Zydeco during their Stickies evaluation.

4.3 Design Session #3 – Layered Elaboration

4.3.1 Context and Setup

In the following spring we ran Layered Elaboration sessions with Kidsteam and KC to review a prototype interface of ScienceKit. For Kidsteam, six children (3 girls, 3 boys, 7-11 years old) and seven adult designers participated. All the children had previous experience with this technique and had co-designed together on other projects for one to two years. Five out of six of the children

in this design session had already reviewed the apps in Design Session #2.

In the Kitchen Chemistry afterschool implementation, six children (one girl, five boys, 8-11 years old) and five adult facilitators spent one day a week for twelve weeks together working on their food investigations. The KC children in this group used Zydeco and StoryKit, as well as SINQ, to help them generate questions, hypotheses, and investigation ideas. However, for this group of KC children, this Layered Elaboration session was their first and only attempt at co-designing technologies. The afterschool session was done on week eight and was divided into three parts. During the first two parts, the participants completed a food investigation from a prior week and worked on developing new investigations. The third part was devoted to Layered Elaboration.

We asked the children in both groups to help us develop a better design for the interface and usability of ScienceKit. We prepared seven design panels, each representing a paper prototype of a ScienceKit screen. Since the KC team could only examine three panels in the available limited time, we only compare the results of elaboration on those three panels. Both groups completed three transparency layers on top of the paper prototype. The three panels were (1) new investigation, (2) story screen, and (3) conclusion to investigation. After completing a layer the children presented their ideas while an adult recorded them on the board. Once all the ideas for all panels were captured, we counted the number of ideas for each panel. Figure 5 shows the frequency count of the number of ideas each co-design team made per panel. Each count represents an idea the children expressed during their presentation of their panels.

4.3.2 Comparative Findings

Similarities: Kidsteam and KC design partners desired similar features for the ScienceKit prototype. Both groups wanted ways to customize the technology with different backgrounds, avatars, and themes. They suggested that greetings and introductions could be present in Panel (1). All groups looked for some sort of help from ScienceKit to guide them in Panel (2). In Panel (3), instead of typing text, all co-designers wanted multiple ways to input their claims, evidence, and reasoning, such as using integrated media to record a hypothesis or use a photo to capture evidence.

Similar, but different: The children all focused on the buttons of the interface, but the two design teams had different foci. Both groups emphasized buttons for practical needs, such as adding notes, deleting content, editing content, managing settings, and resetting the app. KC co-designers asked for only two buttons that went beyond pragmatics: a button for calling a food expert and a button that launches games, while Kidsteam children asked for a myriad of unorthodox features, such as a "pet button" (customized mascot for ScienceKit), "tips button" (random science facts), "send" button (send the ScienceKit investigation directly to friends), and a "touch" button (exhibits a random surprise).

Differences: The Layered Elaboration design session displayed more differences and fewer similarities than the other two cases.

Amount of elaboration: Kidsteam children tended to add more ideas per panel than KC participants. Figure 6 shows an example in which the drawings from Kidsteam on Panel (3) are more plentiful than those on the KC children's panel. In a side-by-side comparison between each panel, we observed that Kidsteam children drew as much or more than KC children on the layers.

Open vs. practical ideas: Kidsteam children tended to present more expansive, less constrained ideas, while KC children focused on practical implementation. KC designers focused on usability issues such as bigger boxes for text entries, date and time stamps on the stories, switching between Fahrenheit and Celsius for temperature input, and using more integrated media to capture data. Kidsteam designers tended to develop more unconstrained and open ideas, such as a friend finder for food investigations, a digital mascot for ScienceKit, and switching between a fun children's perspective versus a "science" view. This is not to say that KC designers did not have open ideas. Some KC co-designers asked for a ScienceKit game.

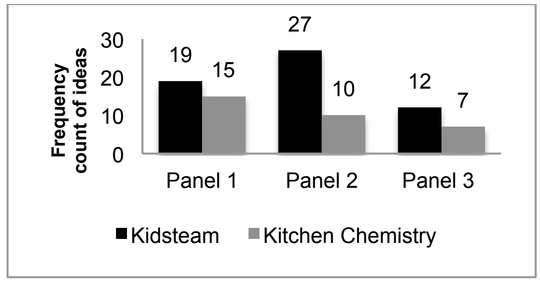

Figure 5. Frequency count of design ideas on the panel

Figure 6. Kidsteam (left) and KC (right) example panel.

Multiple interactions: Panel (2) prompted learners to design ways to input temperature. KC children only wrote one idea, that is, to change between the temperature units. Kidsteam co-designers greatly emphasized the interaction. For instance, we counted eight different ideas just for a thermometer, including color as a way to tell temperature, a hypothesis section just for temperature, and the ability to drag temperatures onto a picture for labeling.

Critical opinions: We found that Kidsteam design partners were more likely to be critical and tell us what they disliked about the design. One Kidsteam child said that the design was "boring" and that it reminded her too much of school. Another said that she "did not like" the buttons on the prototype. The KC children did not express this kind of negative feedback.

4.3.3 Session Analysis and Discussion

During the Layered Elaboration session both the depth of relationships and the practical implementation of co-design contributed to some of the differences in the ideas. As mentioned before, the Kidsteam children's relationship was based on design. The children in this session had one to two years of design experience and participated twice a week after school on our design team. They had experience with the Layered Elaboration design technique, so it is not unusual that the Kidsteam children would have been more comfortable writing on the layers. Our Kidsteam relationships had developed to the point that the children often expressed inside jokes. For example, in the design of the panels, the Kidsteam children kept adding a "Do Not Touch" button, a button in which random surprises would occur when pushed. Kidsteam children who included it in their panels knew what this meant. We see this design suggestion as a

signature or brand for Kidsteam co-designers. The children see this co-design process as fun, social, and personal [11].

Relationships within Kitchen Chemistry were based on cooking and designing food investigations. The Layered Elaboration co-design session with the KC children proved harder logistically. Because Kitchen Chemistry has other goals (e.g., science inquiry learning), scheduling time for co-design is a challenge. The children had to complete other activities before engaging in the co-design task. Therefore, possible reasons for less writing and fewer design ideas on the panels could be due to fatigue. Layered Elaboration can also be a complex task for children who are not used to co-design. It assumes children can design collaboratively and that they are able to present their design ideas [19]. In Kidsteam, Layered Elaboration is done first as practice and is only used in real design tasks after the children are familiar with it. In the KC case, the children used Layered Elaboration in the design of ScienceKit without rehearsal. Anecdotally, one child – Charlie (pseudonym) – in the KC group had a difficult time with this co-design exercise. When we asked him to come up with an idea for temperature inputs for ScienceKit on the iPad™ for Panel (2), he adamantly said it was "impossible" because the iPad™ does not support these kinds of inputs. Here, Charlie's disbelief that we could manipulate and design software for our project prevented him from wanting to develop more expansive and unconstrained ideas.

We also noted in cases #2 and #3 that Kidsteam children generated more open ideas about usability and interface than the KC children. While some ideas are unfeasible (e.g., pet button), the volume of ideas is important for two reasons. First, quantity can corroborate what a designer suspects with usability. For example, the sheer numbers of new ideas for the temperature interface means that we should not take design options for temperature input lightly. Second, idea generation is part of the collaboration and brainstorming process. As more ideas are developed, more novel approaches can be designed.

5. DISCUSSION AND IMPLICATIONS

Our overall analysis of these two cases suggests that there is benefit to designing with both child design and subject experts. There is benefit in discovering the similarities and differences of their designs as well as the different emphasis in in certain aspects of design. We therefore make specific recommendations for using CI with subject expert children (5.1); describe implications for conducting CI with both child design and subject experts (5.2); and demonstrate how our CI work both supports and extends activity theory (5.3).

5.1 Cooperative Inquiry with Child Subject Experts

We recognize that designers of learning technologies may or may not have access to children with extensive design expertise (e.g., Kidsteam). However, based on the findings of these case studies, child subject experts are suitable partners for co-design, providing beneficial design insights. Our findings suggest that many design overlaps did exist between the Kidsteam and the KC children. Children with subject expertise were able to recognize many similar issues with interface and usability and make comparable design recommendations (e.g., Design Session #1). They also provided unique design ideas regarding the domains of cooking and scientific inquiry. In order to work best with children subject experts we make the following recommendations:

Choose the co-design technique carefully. Not all co-design techniques are equally implementable, as some techniques are more complex than others [19]. These case studies suggest that co-design techniques that are more familiar to children with little design experience may work best. As seen in Design Session #1, techniques that use arts and crafts to create paper prototypes, such as Big Paper [10] and Bags-of-Stuff [7], may be easier to implement, while Design Session #3 showed that a complicated technique like Layered Elaboration can be difficult for first time designers.

Co-designers who are not asked to criticize may not criticize. We found that Stickies, a co-design technique that asks children explicitly to give their opinions on likes and dislikes gave the subject experts the opportunity to be critical. However, using Layered Elaboration, our KC partners were less likely to provide negative feedback. We recommend that designers be explicit in soliciting negative feedback and make sure child designers are comfortable in giving honest feedback to adults with whom they may not have developed design relationships [9].

Designing with child subject experts may mean designers have few opportunities to do so. Due to the practical constraints of a learning environment, child subject experts need time to shift from domain to design activities. Other constraints include how tired the children might be, what days can be planned for design, and how much interaction with the researchers the children are expected to have in the learning environment. Consequently, co-design sessions with child subject experts need to be planned accordingly. In our setup, we had to run co-design sessions at the end of Kitchen Chemistry sessions. We worked with two different groups of children across the summer and afterschool program. In contrast, for Kidsteam, we were able to co-design with the same children over a longer period of time.

Designers can focus on usability through observation. Subject expert children can be very good at expressing their technology needs, but have more difficulty explaining implementation and usability issues. For this reason, we suggest adult co-designers could be especially attentive to implicit usability issues, if child design experts are not available. If subject expert children are testing a system or prototype, observing the children may identify possible usability problems that are not verbalized or reported.

5.2 Cooperative Inquiry with Child Design and Subject Experts

We observed different affordances and practical constraints with both design teams. We found that Kidsteam co-designers developed a relationship with other children in the context of design. As child design experts work with many technologies with adult researchers, over time they develop insights about the potential of technology and become familiar with a variety of design techniques. Our findings suggest it can be more difficult for child design experts to understand the learning contexts for which they are designing. Subject experts' understanding of the structure and the context of the learning environment often enable them to express domain specific priorities and identify the needs of the technologies for their learning activities. However, working with subject expert children may present practical challenges. Based on our observations of the two groups of children, we make the following suggestions for PD and CI researchers.

Limitations in time: Design expert children often participate in Kidsteam because they like to design with adults [11]. While we engaged Kidsteam in brief activities that mimicked KC, the amount of time it would have taken to fully acclimate the Kidsteam to the Kitchen Chemistry program would have been extremely time consuming (about 25 – 30 hours). Trying to get

Table 1. Summary of findings

Similarities	Differences	Similar, but different
Bags-of-Stuff (1)		
• Familiar interfaces • Process displays • Scaffolds and guidelines • Sensors	• KC focused on reference and information retrieval; Kidsteam made no mention of this	• *Mobility:* Both emphasized mobility, but KC focused more on unobtrusiveness • *Gamification:* Both mentioned games, but KC focused on games in context • *Social:* Both described social features, but KC focused on more interaction with a community
Stickies (2)		
• Wanted more integrated media and usability and audio recording issues (Zydeco and StoryKit) • Wanted more "child" like feel and wanted tagging to be like a game (Zydeco)	• Kidsteam wanted more social interactions and organizational tools • KC emphasized that multitasking between cooking and using the technology is important	• *Customization and control:* Kidsteam focused on aesthetics; KC focused on interaction • *Narrative in Zydeco:* Both wanted this feature, but KC were more vocal about it than Kidsteam • *Tagging:* Kidsteam emphasized specific details on how to tag; KC expressed generalities about tagging
Layered Elaboration (3)		
• Customized greetings and themes • Help for food investigations • Integrated media to input data	• Kidsteam generated more ideas, were more comfortable with design technique, and giving negative feedback	• *Buttons on the interface:* Kidsteam had more open and unconstrained ideas; KC focused on pragmatic and practical ideas

children to become experts at both subject and design domains could be problematic. First, design expert children could be alienated because they spend too much time in a subject area, not in design activities. Second, the "mile wide, inch deep" phenomenon can occur; that is, children's knowledge becomes superficial. In Contextual Inquiry [2], designers collaborate with expert users in context, without becoming subject matter experts.

Triangulation: We recommend if possible, that researchers developing learning technologies for specific contexts work with both subject and design expert children to triangulate the data and design findings. Often, we found that the KC children could express exactly what they needed, but they had a difficult time articulating how to implement that need. One new possibility for triangulation is to run a subject expert design session first to identify high priority needs. For instance, this study shows that subject expert children who design early low-fidelity prototypes using arts and crafts can identify many needs. After the needs are identified, researchers could present these needs to design expert children and have them develop ideas for the usability, aesthetics, and interaction for other children. In middle stages of development, design expert children can critique the interface evaluation techniques. We are not promoting the idea that children's exposure to design and context is the only factor that influences the design ideas we observed in our analysis. As we mentioned before, other factors such as which design technique is chosen and the practical constraints of the sessions also matter.

Subtle and explicit: Similar to triangulation, different groups of child designers will make their recommendations known in more subtle or explicit ways. Beyer and Holtzblatt [2] write that users often have a difficult time expressing what technology features they actually need to designers. Our findings suggest that subject and design experts will articulate similar needs with different details. Having perspectives from both subject and design experts can be important for understanding the range of possible needs for learning technologies in contexts.

5.3 Activity Theory and Cooperative Inquiry

Our work extends Nardi's [16] methodical implications from activity theory; specifically, her call to understand users' points of view in HCI design and research. Users often have difficulty clearly articulating what they need or want in technology [2]. Consequently, many HCI researchers attempt to understand users' contexts through passive observational studies. However, user interviews provide valuable information about the contextual circumstances and constraints under which users operate – data that is not possible with passive observation alone [16]. In short, user interviews are a valid methodological means for "understanding the user's point of view" [16]. As a design method, CI includes both observations and interviews as a means for understanding and triangulating children's design ideas. Indeed, we found that because CI involves working with children directly, as full design partners, we were able to more deeply understand the "user's point of view." CI deepened our understanding of users' activities, contexts, and technology needs. The equal design partner aspect of CI also reinforces the activity theory premise that an indivisible relationship between user activity and user context exists, and it must be preserved if we are to design technology that optimally serves users. Finally, activity theory implies that the cultivation of close design collaborations between user and design researcher will enable users to attain a deeper level of meta-awareness of their own actions and needs, which will in turn, support their efforts to explicitly articulate those design needs. Given our close partnerships with both design and subject expert child designers, the data from our study suggests that both types of child designers were able to develop a meta-awareness that enabled them to more explicitly articulate their design desires.

6. LIMITATIONS

Logistical considerations: We realize that practical and logistical timing issues might have influenced the differences in the social collaboration theme. Specifically, we acknowledge the differences between the Bags-of-Stuff and Stickies design session for KC. As noted before, the KC partners emphasized social collaboration as an important design feature in the Bags-of-Stuff design session. However, in the Stickies session, this was not apparent. During the summer design session for KC, we conducted the Stickies evaluation of StoryKit on day two and both the Zydeco review and Bags-of-Stuff on day five. Therefore, we speculate that the early implementation of Stickies on day two did not allow for the

KC participants to solidify their collaborative relationships. It was not until day five in the Bags-of-Stuff session that the KC children mentioned social collaboration as important. However, several children in the Kidsteam session already knew each other and felt comfortable sharing and collaborating.

Theoretical limitations: A second limitation of this study is that this is a single exploratory investigation of comparing subject and design expertise in children's co-design. Therefore, the implications of this study are specified to make analytical generalizations and theoretical propositions, as opposed to statistical generalizations [21]. The findings in these case studies are not meant to directly compare between subject and design experts, but instead are meant to examine the practical implications of designing with multiple groups of children who have different types of expertise.

7. CONCLUSIONS AND FUTURE WORK

Our study builds on work that addresses the importance of context in technology design [16] and children's contextual familiarity in PD [13]. Our findings extend our understanding of co-designing with children in context by considering the role that users' subject and design expertise have in informing the co-design of learning technologies. We show the importance of designing with different groups of children with differing domain expertise. Our work contributes to learning technologies design and PD research by exploring how the design and subject experience of child designers influence design, and by offering an initial set of suggestions for engaging both sets of children in the CI process. We suggest that future studies be conducted to examine further how domain knowledge in children affects other designs of learning technologies. Specifically, we recommend more comparative examinations between subject and design partners to see if other distinctions exist. Other comparative studies may include adolescents and how knowledge of content and subject matter influences the co-design process. In particular, adolescent Kidsteam members may have both subject and design expertise. Lastly, studies that examine leveraging child partners with different domain-expertise at different times will be further beneficial to understanding the limitations and affordances of CI.

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