Cooperative Inquiry: Developing New Technologies for Children with Children

Allison Druin
Human-Computer Interaction Lab
University of Maryland
College Park, MD 20742
+1 301 405 7406
allisond@umiacs.umd.edu

ABSTRACT

In today's homes and schools, children are emerging as frequent and experienced users of technology [3, 14]. As this trend continues, it becomes increasingly important to ask if we are fulfilling the technology needs of our children. To answer this question, I have developed a research approach that enables young children to have a voice throughout the technology development process. In this paper, the techniques of *cooperative inquiry* will be described along with a theoretical framework that situates this work in the HCI literature. Two examples of technology resulting from this approach will be presented, along with a brief discussion on the *design-centered learning* of team researchers using cooperative inquiry.

Keywords

Children, design techniques, educational applications, cooperative design, participatory design, cooperative inquiry, intergenerational design team, KidPad, PETS.

CHILDREN AS OUR RESEARCH PARTNERS

Today's technologies are becoming a critical part of our children's daily lives [3, 9, 14]. From school learning experiences to after-school play, technology is changing the way children live and learn. In fact, children have been found to be an important new consumer group that must be satisfied as technology users [17].

In recent years, numerous methodologies have been developed that bring technology users into the development process. Users have been described as active partners [6, 16, 29], inspectors or testers [24, 25], or research participants to be observed and/or interviewed [5, 13, 18]. Thanks to user input, technology can be shaped and changed in ways that may be meaningful and useful for future technology users. While user involvement is well understood as important to the technology research and development process, users that are children are less commonly involved than adults [9, 10]. When children's input is sought out, it is typically done so over short periods of time (e.g., a day, a few weeks, perhaps a few months). Children are most frequently asked to be technology testers in workshops or school settings [e.g., 20, 26]. However, researchers have begun to see the limitations of what children can contribute in these situations [10, 27].

During the past four years, my research has involved children as active research partners. Some people question whether children are capable of contributing throughout the research and development process [27, 28]. I believe that children can and should be partners throughout a team research experience. Just as computer scientists or educators may be limited in their range of experience, so too are children. But each has their own expertise to contribute depending on what the team needs are during the research and development process. The intergenerational teams I have led have included members with diverse ages, disciplines, and experience [10, 11]. Children have been an essential part of these teams, along with educators, computer scientists, and artists.

Initially, the activities of our teams were structured to reflect methodologies that call for bringing *adult* users into the design process (e.g., cooperative design, participatory design, contextual inquiry). While these methodologies offered an excellent starting point for us, we quickly found that they needed to be adapted and changed to suit our teams that included children. Over the years, our interview procedures, note-taking practices, data analysis, and day-to-day team interactions evolved to become more inclusive of our child partners. This has lead to the development of *cooperative inquiry*, an approach to creating new technologies for children, with children.

This paper will present a theoretical framework that situates cooperative inquiry in the HCI literature. In addition, the research techniques of cooperative inquiry will be discussed, and two examples will be given to

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demonstrate this approach. This paper will conclude by describing another critical outcome of the cooperative inquiry process: *design-centered learning*. Self-reported learning in areas such as team collaboration and communication skills will be discussed.

A THEORETICAL FRAMEWORK

While cooperative inquiry is unique in many aspects due to child involvement, it is also grounded in HCI research and theories of cooperative design [16], participatory design [29], contextual inquiry [5], activity theory [23], and situated action [32]. Cooperative inquiry is an approach to research that includes three crucial aspects which reflect the HCI literature above: (1) a multidisciplinary partnership with children; (2) field research that emphasizes understanding context, activities, and artifacts; (3) iterative low-tech and high-tech prototyping. These three aspects form a framework for research and design with children. In the sections that follow, this framework will be discussed as it relates to other HCI research and theories.

Multidisciplinary Research Partnership with Users

Cooperative inquiry is based upon the belief that partnering with users is an important way to understand what is needed in developing new technologies. This belief can be seen in work done over the last 20 or more years in the cooperative design of Scandinavia [6, 16], the participatory design of the United States [15, 21, 29], and the consensus participation of England [22]. As Greenbum and Kyng have explained [16], "We see the need for users to become full partners in the cooperative system development process….Full participation of (users) requires training and active cooperation, not just token representation" [pp. ix-1].

This partnership between users and researchers from different disciplines was exemplified in the Scandinavia cooperative design work beginning in the 1970s. It was during this time that employee influence through trade unions grew, and collaborations between workers, management, and researchers influenced how new technologies could be created for and used in the workplace. Cooperative design methods supported the development of new technologies for carpenters, typographers, bankers, manufacturers, and more [6, 16, 29].

This approach to design attempted to capture the complexity and somewhat "messy" real-life world of the workplace. It was found that many times there were not sequential tasks accomplished by one person, but many tasks done in parallel and in collaboration with others. Interestingly enough, this description could also easily refer to the complexity and "messiness" of a child's world. In any case, this workplace design approach was not confined to the Scandinavian countries for long. Today researchers from around the world are applying these ideas and practices in their own work [1, 2].

Field Research: context, activities, and artifacts

Cooperative inquiry is also grounded in the traditions of field research. A great deal of information can quickly be understood about the needs of users from the activities and artifacts that are a part of a user's context. Contextual design [5, 18], activity theory [23] and situated action [7, 32] all discuss the importance of these crucial elements in researching and developing new technology. It is the methodology of contextual inquiry (now a part of the contextual design process) that our intergenerational design teams found most useful with children.

With contextual inquiry, a team of researchers observe and analyze the users' environment for patterns of activity, communication, artifacts, and cultural relationships. Diagrams and models are developed from field experiences that eventually may lead to the design of storyboards, prototypes and new technology [5]. It is from this type of research inquiry that the method "cooperative inquiry" gets its name. I have found that this process of capturing field data, is extremely important in working with children as research partners. Young children, particularly from ages 3-7 have a difficult time abstractly describing what their technology needs and wants may be. When discussions take place in the context of a child's home, school, or public play space, it is much easier for the child to express his/her ideas [10]. Later in this paper this modified form of contextual inquiry with children will be described.

Iterative Low-tech and High-tech Prototyping

The third aspect of cooperative inquiry calls for intergenerational design teams to visualize their ideas through prototyping techniques. Again, since children may have a difficult time communicating to adults exactly what they are imagining, prototyping offers a concrete way to discuss ideas. The "low-tech prototyping" or "mock-ups" found in the cooperative design and participatory design literature [12, 21] have been an inspiration for my work with children.

By using paper, crayons, clay, string and more, low-tech prototyping gives equal footing to child and adult [10, 21]. There is never a need to teach people how to prototype, since using basic art supplies comes naturally to the youngest and oldest design partners. This form of prototyping is inexpensive, yet quite effective in quickly brainstorming new ideas or directions [10]. It is from these low-tech prototypes that high-tech prototypes emerge. As team ideas evolve, continued iterations of prototypes are developed. In the section that follows further description of prototyping with children is described.

COOPERATIVE INQUIRY: THE RESEARCH METHODS

Based upon the previous theoretical framework, the cooperative inquiry approach to partnering with children has become a reality. The goal in developing cooperative inquiry was to find techniques that can support intergenerational design teams in understanding what children as technology users do now; what they might do tomorrow; and what they envision for their future. It is not easy for an adult to step into a child's world, and likewise it is not easy for a child to step into an adult's world. I have found no single technique that can give teams all the answers they are looking for, so a combination of techniques has been adapted or developed that form the methodology of cooperative inquiry. These techniques do not necessarily offer a magic formula for working with children, but rather a philosophy and approach to research that can be used to gather data, developing prototypes, and forging new research directions.

At the University of Maryland, we use cooperative inquiry with an on-going intergenerational design team. I chose to establish this on-going partnership rather than work with many different children over short periods of time. In this way, children are not subjects for testing, but research partners who I have come to know and respect. Children and adults alike gather field data, initiate ideas, test, and develop new prototypes. Team members do what they are capable of, and learn from each other throughout the process.

The current team includes two faculty members, two graduate students, two staff members and six children (ages 7-11 years old). The disciplines of computer science, education, robotics, and art are represented. Members of the team meet two afternoons a week in our lab or out in the field. Over the summer we met for two intensive weeks, eight hours a day. At the time of this writing, the team has been together for almost a year and is expected to be together for almost two years.

In the sections that follow, the three techniques that comprise cooperative inquiry will be explained.

Contextual Inquiry

The first technique adapted for use with children is *contextual inquiry*. This is based upon the work of Beyer and Holtzblatt [5]. What their work tells us is that researchers should collect data in the users own environment. However, in our case at the University of Maryland, the researchers are not just adults who gather data from a child's world. Both adults and children observe, take notes, and interact with child users. Children are expected to be researchers along with their adult partners. This differentiates this form of contextual inquiry from that of others who work with users as informants but not necessarily as researchers [5].

At first, we attempted to have all team members take notes in the same way. This was too difficult for both children and adults. The adults in our team saw the need to gather data by writing detailed text descriptions. But the child researchers could just not accomplish this in a way that yielded meaningful results. On the other hand, the children wanted to combine drawings with small amounts of text to create cartoon-like flow charts (see Figure 1). The adult team members using this method felt too self-conscious about their drawings and were concerned that they would miss the details needed. Therefore, the team compromised and adults developed their own note-taking forms and the children developed theirs.

For adults, note-taking occurred most effectively in pairs. One note-taker recorded the activities of the child(ren) being observed and the other note-taker recorded quotes of what was said. Both note-takers recorded the time so that the quotes and activities could be synchronized in later data analysis.

Our team does not find video cameras to be successful in capturing data for contextual inquiry purposes. In my previous work at the University of New Mexico we also did not find video useful [10]. We found that when children saw a video camera in the room, they tended to "perform" or to "freeze". In addition, even with small unobtrusive cameras, we found it difficult to capture data in small bedrooms and large public spaces. The sound captured in public spaces was difficult to understand. In addition, we found that the video images were incomplete in private spaces. It was difficult to know where to place cameras when it was unknown where children would sit, stand, or move in their own environment.

During the note-taking experience, there were at least two note-takers and always one researcher who was an *interactor*. The interactor did not take notes but instead, was the person who initiated discussion and asked questions concerning the activity. We found that if there were no interactor, the children being observed would feel uncomfortable—as if they were "on stage." We also found that if the interactor took notes, the children being observed clearly felt uncomfortable and distracted. Instead, we found that the interactor should become a participant observer, talking naturally to children, free from note-pads, and becoming a part of the active experience. This is very different from contextual inquiry experiences with adults where note-taking is less of an issue.

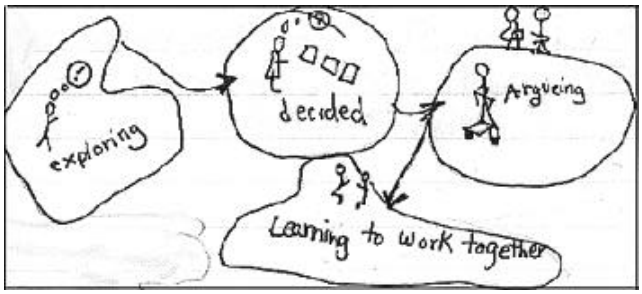

Figure 1: Contextual inquiry notes by a 7-year old child

Interestingly enough, we found that child researchers had a difficult time being interactors. Children would tend to get involved in what was going on and forget that they were there to do research and should let the other child lead the action. On the other hand, adult researchers also had a difficult time being interactors. Traditional "power structures" or relationships between adults and children could easily emerge, where adults could tend to steer the child(ren) being observed as a parent or teacher might. One way we found that helps change these traditional power structures is to have adults wear informal clothing so that they look less like an authority figure, and more like a peer.

The interactor should not to be confused with an interviewer. The interactor is not there to ask hours of questions that might force the child(ren) being observed to stop what is naturally being done. Instead, the interactor is there to ask questions that are directed to what is going on at the moment (e.g., How come you're doing that? Why do you like that? What's this?). In this way, the interactor is annotating the activities with information for the note-takers to capture.

After the field research experience, the team typically meets back at the lab to analyze the captured data. Our technique of visualizing the data gathered, again diverges from the techniques of Beyer and Holtzblatt [5]. We have found that children's activities are often more exploratory than task-directed, especially when children are not told what to do by an adult parent or teacher [10]. We are most interested in capturing these exploratory experiences, for they tell us what children want to do as opposed to what adults expect of them. In our experience, the diagrams or models suggested by Beyer and Holtzblatt became extremely complex and difficult to understand when trying to capture the exploratory experiences of children. Therefore, we found it more effective to diagram these experiences based on *Patterns of Activity* and *Roles the Child Played* [10]. In Table 1, a portion of the information gathered by an adult researcher is shown. This information is broken up into six columns: *Time*, *Quotes*, *Activities*, *Activity Pattern*, *Roles*, and *Design Ideas.*

The *Time* column is used to synchronize quotes with activities. The *Quotes* column contains phrases and sentences said by the child(ren) during a session. The *Activities* column contains the observed actions of the child(ren) during a session. While the first three columns contain raw data from observations, the *Activity Pattern* column is developed by the researchers during data analysis and is based on repetitive patterns that emerge in the *Quotes* and *Activities* columns. The *Roles* column is also developed by the researchers, from the data in the *Quotes* and *Activities* columns. The *Roles* column describes "the who" children are when they are interacting with technology (e.g., searcher, storyteller, researcher, learner, etc.). Finally, the last column contains the *Design Ideas.* It is a culmination of all the information gathered or generated. This column is also the start of the brainstorming process. It offers new ideas for the development of technology that can be related directly to the observed data. When someone asks, "Where did that idea come from?" it is easy to refer back to the related data.

Once these adult notes have been compiled for a session, the adult diagrams are compared with the child notes. The adult diagrams are highlighted in the places that the child researchers have recorded in their notes. In this way,

RAW DATA:			DATA ANALYSIS:		
Time	**Quotes**	**Activities**	**Activity Patterns**	**Roles**	**Design Ideas**
39:20	"I want the playing one."	Child clicks on the scared cat and tries to take out another one. It doesn't work.	Difficulty with mouse dragging.		Look for alternative input devices or don't use dragging with a mouse.
39:50	"Awww. The kitten was afraid."	Child clicks on another basket with a cat.	Tells stories about actions on screen.	Storyteller	Offer children storytelling opportunities with technology.
40:20	"Which one's the playful one?"	Child looks for a playful cat.	Child knows what she likes.	Searcher	
41:00	"I don't want to name my kitty."	Child doesn't name her cat when prompted to by the computer.	Child knows what she likes.		
41:30	"That's to give milk."	Child clicks on different icons to see what they do.	Tests out what can be done.	Explorer	Make technology easy to explore.

Table 1: Portion of a contextual inquiry diagram created by adults

child and adult perspectives are captured. It is interesting to note, that many times child researchers offered summaries of the data that enabled adult partners to see something they had originally missed.

Participatory Design

The second technique that comprises cooperative inquiry was adapted from *participatory design.* This is not to say that participatory design techniques must follow contextual inquiry. However, we did find that contextual inquiry enabled us to first explore numerous ideas through observation. Then, during our data visualization, we could focus on an area of interest to pursue in more depth with participatory design prototyping. For example, our contextual inquiry observations led to an understanding that children wanted to be storytellers with technology. This insight was taken into a participatory design session where low-tech materials were used to prototype storytelling technologies for the future. Later in this paper examples of the storytelling technologies that were ultimately developed will be discussed.

In general, I have found that children ages 7-10 years old make the most effective prototyping partners [10]. These children are verbal and self-reflective enough to discuss what they are thinking. They can understand the abstract idea of designing something with low-tech protoyping tools that will be turned into future technologies. Children at this age, however, don't seem to be too heavily burdened with pre-conceived notions of the way things "are supposed to be", something we typically see in children older than 10 years [10].

It is interesting to note that low-tech prototyping is deceivingly simple. It seems that all that is needed are some art supplies, a few children and some adults. But what makes it a difficult process for many adults is relating to children as design partners. Many adults are not quite sure how much they should allow a child to lead and how much they should lead. For example, some adults prefer to sit back and let the children do all the work—they assume that since the art supplies are child-like then the design process is only for children. This is not true. Children and adults must work together. No partner should make all the design decisions, child or adult. In addition, the selection of low-tech protoyping tools is critical. Some researchers feel that it matters very little what materials are given, and that the ideas will emerge whatever the resources. Others feel that a standardized box of materials can be developed for all occasions [Personal Communication, April 1998]. I disagree with both approaches. We have found that the materials need to be purchased with some care to reflect the area of research the team is exploring [10]. For example, the materials I had purchased for a particular session ended up being limited and frustrating to the design team. However the week before, when prototyping a different idea, these same materials (e.g., clay, string, paper, crayons) were just fine.

Whatever the case, the low-tech prototyping materials matter and the team dynamics are critical. This process takes time to understand and facilitate well. Low-tech prototyping is a much more effective design tool when done in concert with contextual inquiry. Based on design ideas that have emerged from contextual inquiry notes, protoyping can focus discussion and be a bridge for collaborative brainstorming activities.

Technology Immersion

Finally, the third technique of cooperative inquiry is what I have come to call *technology immersion* [8]. This process grew out of a need to see how children use large amounts of technology over a concentrated period of time. If children are only observed with the technology resources they currently have, then what children might do in the future with better circumstances could be missed [10]. Many children still have minimal access to technology in their homes or school. If time is not a limiting factor then access to the newest technologies can be. However, in the future we see these limitations changing. Therefore, by establishing today a technology-rich, time-intensive environment for children, the observation techniques of contextual inquiry can be used to capture many activity patterns that might otherwise be over-looked.

With technology immersion, it is critical that children not only have access to technology in a concentrated way, but are also decision-makers about what they do in that environment. Children must be asked to make their own choices when using different kinds of technology. There must be enough technology options so that no child ever has to share a computer if he or she does not choose. There must also be enough time so that children can accomplish a task that is meaningful. Without these ingredients, it is difficult to understand children's technology wants or needs. If adults are fully in control, then the activity patterns seen are those of adults, not children.

I have initiated such technology immersion experiences in my own labs. In addition, I also had the opportunity to establish a technology immersion experience at ACM's CHI 96 conference. This particular experience has come to be called CHIkids and is now an on-going part of the annual CHI conferences [8]. At CHIkids, children explore technology over five days, 10 hours a day, by being multimedia storytellers, software testers, newsroom reporters, and more. This technology immersion experience has come to be more than just another way to understand what children want in technology. It has come to be a way to bring children into the CHI conference as active participants and partners. In a sense, CHIkids can be said to be a very large intergenerational design team (at CHI 98 we had over 65 child and 25 adult participants).

But not every technology immersion experience needs to be on the scale of CHIkids. Our design team recently shared an experience between six children and six adults over 10 days, 8 hours a day. In those 10 days we came to understand more about children's activity patterns and roles than in the last six months of our research combined. This is not to say that a technology immersion experience isn't exhausting. It is. It may be the most difficult of the cooperative inquiry techniques, since it is so intense. In addition, during such an experience, tempers can flare, energy wears thin; the space never seems to be big enough; but all in all, it is an exciting experience to see what children can do with technology [8]. Technology immersion in combination with contextual inquiry and low-tech prototyping can be extremely effective in highlighting patterns and roles that are not obvious in short contextual inquiry sessions. We have found technology immersion experiences most useful after initial contextual inquiry and participatory design sessions have been done.

COOPERATIVE INQUIRY IN PRACTICE

Two projects over the past three years demonstrate our use of the cooperative inquiry process. When we began these projects, our methodology was still being developed, and what we did wasn't even given a name. Over time, the common research practices became more obvious, and cooperative inquiry took form. In a sense, cooperative inquiry was as much a part of what our design teams developed, as the technology that was created.

KidPad

KidPad was our first example of using cooperative inquiry [10, 11]. This technology, based upon Pad++ [4], was first developed at the University of New Mexico and continues to be developed at the University of Maryland. KidPad is a zooming storytelling tool that enables children to collaboratively create stories (see Figure 2).

The act of zooming from one story object to the next, makes visually explicit where children are going and where they have been. In traditional applications that don't use zooming to navigate, different objects that are semantically related are linked visually by jumping from one object to the next (e.g., links on the web). Children have explained this as "…closing your eyes and when you open them you're in a new place. Zooming lets you keep your eyes open" [10].

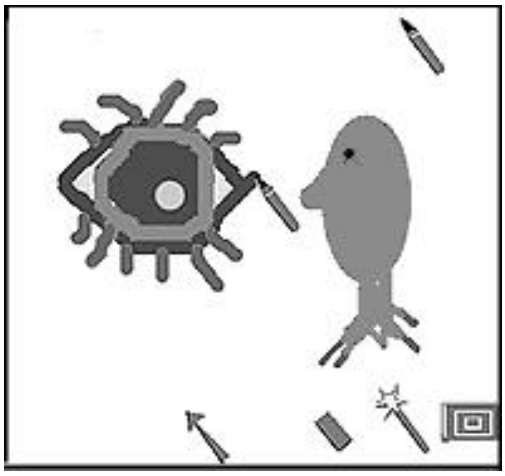

Figure 2: "The Eye", a story made in KidPad

In one example shown above (see Figure 2), a group of three Native American children (age 8) from New Mexico created a zooming story. It was about an eye "that could see what you looked like on the outside and on the inside, and even more on the inside. It could see your questions." In their story, the eye had special powers and could zoom in to see that the boy felt like a girl inside. The eye could zoom in even more and see the boy was asking why this was so. The story ended with the eye explaining to the boy, "You are both inside and outside. There is no reason to ask why" [Research notes, October 1996].

To develop KidPad, a team of educators and computer scientists worked with over 40 children (ages 8-10) in the New Mexico public schools. While we had not yet established an on-going intergenerational design team, the techniques of cooperative inquiry were used in formative studies. A version of contextual inquiry was used where only adults were observers, but the diagramming techniques previously described were used. Low-tech prototyping also contributed to our ideas, but was done only on special occasions for conference tutorials and industry workshops. At both CHI 96 and CHI 97, KidPad was tested during the technology immersion experience of CHIkids. All of these early cooperative inquiry techniques led to the development of KidPad. Children told us in many ways that they wanted to be collaborative storytellers using technology.

Our work continues today on a collaborative version of KidPad where two mice can be used simultaneously to create zooming stories [31]. For more details on the KidPad environment see [11].

PETS

Another research project we have developed using cooperative inquiry techniques is PETS: a Personal Electronic Teller of Stories (see Figure 3). While this is also a storytelling technology, it is quite different from KidPad. The PETS environment makes use of physical robotic animal parts to enable children to build fanciful

animals that can act out the stories they write. This project is being developed at the University of Maryland with our intergenerational team of researchers. We began our work on this project by conducting field research in the university's robotics labs, using the contextual inquiry techniques previously described. Participatory design sessions with low-tech prototyping followed. From this, high-tech prototypes were begun. Over the summer, we had a technology immersion experience where we solidified our ideas and developed new directions for the future. For more details on the PETS research, see the CHI 99 video paper, in these conference proceedings.

Figure 3: PETS robotic storytelling animal

DESIGN-CENTERED LEARNING

Typically when people consider the outcome of a design process, it is the technology that is discussed. To me, this is important, but is not the only result of my work. I find what the team members can learn as a result of the research and development experience to be critical. There are many references to this learning as an outcome of the cooperative or participatory design process [12, 15, 22]. In addition, there are also educational researchers that refer to this kind of learning as a *community of practice* [19]. They describe this to be a community of people with different skills that learn as they work toward shared goals. This leaning experience has also been described by Shneiderman as *Relate—Create—Donate*, where students can have a meaningful learning experience with technology by using it to perform a service to the community [30].

I give the name *design-centered learning* to learning outcomes that can be related to the cooperative inquiry process. Design-centered learning occurs in both children and adults, novices and technology experts, technical and non-technical professionals. When diverse people partner together in the research and design process, design-centered learning can emerge. By surveying an intergenerational team over time, I have seen five areas of self-reported design-centered learning [Research notes, August 1998]:

(1) I learned about the design process All team members discussed understanding the technology design process in new ways.
(2) I learned respect for my design partners Both adults and children discussed their mutual appreciation for the work that the other could accomplish.
(3) I learned to communicate and collaborate in a team Children and adults discussed the difficulties and the rewards of learning team communication and collaboration skills.
(4) I learned new technology skills and knowledge All team members mentioned technical skills they had come to learn (e.g., building robots, designing software).
(5) I learned new content knowledge In the case of the team working on the PETS project, children and adults discussed learning more about animals.

Table 2: Self-reported design-centered learning

These design-centered learning outcomes were summarized after children and adult team members were asked to write on Post-It Notes what they thought they might have learned from their team research experience. Each participant voluntarily wrote ideas. When all were done, the notes were stuck on a whiteboard to analyze by the team. This summary was completed after working together for six months (Phase I of our research). A second study on Phase II will be performed using a variety of data collection methods after a year of team work. It is expected that this study will describe intergenerational team changes in communication, collaboration, and design-centered learning.

SUMMARY

In summary, cooperative inquiry has been developed to support intergenerational design teams in developing new technologies for children, with children. While this approach requires time, resources, and the desire to work with children, I have found it a thought-provoking and rewarding experience. Cooperative inquiry can lead to exciting results in the development of new technologies and design-centered learning. The cooperative inquiry methodology continues to evolve as we use the techniques over time. In addition, a new intergenerational team will be established shortly at the University of Maryland that will be compared to the existing team.

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