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The Role of Children in the Design of New Technology

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Abstract
This paper suggests a framework for understanding the roles that children can play in the technology design process, particularly in regards to designing technologies that support learning. Each role, *user*, *tester*, *informant*, and *design partner* has been defined based upon a review of the literature and my lab's own research experiences. This discussion does not suggest that any one role is appropriate for all research or development needs. Instead, by understanding this framework the reader may be able to make more informed decisions about the design processes they choose to use with children in creating new technologies. This paper will present for each role a historical overview, research and development methods, as well as the strengths, challenges, and unique contributions associated with children in the design process.

Categories and Subject Descriptors: H.1.2 [**Models and Principles**]: User/Machine Systems—human factors; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—evaluation/methodology; interaction styles

General Terms: Human Factors, Design, Theory

Additional Key Words and Phrases: Children, design techniques, participatory design, evaluation, educational applications

1 The challenges of children and technology

> *Computers for kids need to be fun like a friend, but can make me smart for school. They should also be friendly like my cat. The real thing is that they shouldn't make me have to type since I don't like that. I can talk much better!*
> (Researcher Notes April 3, 1999, Quote from an 8 year-old child).

Children have their own likes, dislikes, curiosities, and needs that are not the same as their parents or teachers. As obvious as this may seem, we as designers of new technologies for children sometimes forget that young people are not 'just short adults' but an entirely different user population with their own culture, norms, and complexities (Berman 1977). Yet, it is common for developers of new technologies to ask parents and teachers what they think their children or students may need, rather than ask children directly (Druin 1996, Druin et al. 1999). This may in part be due to the traditional power structure of the 'all-knowing' adult and the 'all-learning' child, where young people are dependent on their parents and teachers for everything from food and shelter to educational experiences. At times these relationships may make it difficult for children to voice their opinions when it comes to deciding what technologies should be in schools or at home. In addition, we as designers of technologies have our own biases and assumptions about children. Some of us may be parents of our own children, but all of us were once children ourselves with special memories of what we liked and didn't like about the world.

We may also have our own preconceived notions about learning theories and educational strategies thanks to the many years of schooling that we all had to endure (Papert 1972, Solomon 1986, Druin and Solomon 1996).

All of this adds up to a large amount of personal experience about young people that we may choose to bring with us when we develop new technologies for children. However, these personal impressions may not be enough to support today's children. They are fast becoming tomorrow's power-users of everything from the Internet to multimedia authoring tools (Report to the President on the Use of Technology to Strengthen K-12 Education in the United States 1997, Fulton 1997). Yet, they are still children that must go to school and depend on their teachers and parents for learning and living in this complex world.

In addition, as we know, young children have a more difficult time verbalizing their thoughts, especially when it concerns abstract concepts and actions (Piaget 1971, Piaget 1973). For example, if children become bored by a task an adult asks them to do, they may simply walk away, start to distract another child, or even begin to find interesting ways to bang on a computer keyboard. They are 'acting out' rather than directly confronting the issue with a discussion as an adult might do. This kind of behaviour can easily be misinterpreted by adults who may be led to think that children have limited attention spans, are uninterested in cooperation, or are even destructive. Children are extremely honest in their feedback and comments concerning technology, but much of what they say may be in their actions and therefore, needs to be interpreted within the context of concrete experiences (Druin 1999).

For all of these reasons, a child's role in the design of new technology has historically been minimized. In the Human-Computer Interaction (HCI) community, we have a short but rich history of developing shared paths for communication between diverse users and technologists. However, this history of shared communication is even shorter and less developed for our children in the technology design process.

2 The emergence of children in the technology design process

A growing body of literature has emerged that discusses children, technology and human-computer interaction issues. Once relegated to one or two conference papers a year (e.g. Malone 1982, Gulian et al. 1984, Frye and Soloway 1987, Verburg et al. 1987, Wilson 1988, Nielsen and Lyngbaek 1989) today's HCI conferences include multiple paper sessions, panels, demos, and tutorials on these topics (e.g. Colella et al. 1998, Loh et al. 1998, Smith and Reiser 1998, Umaschi Bers et al. 1998, Druin 1999, Salzman et al. 1999, Stewart et al. 1999, Frei et al. 2000, Ketola and Korhonen 2001, Wyeth and Wyeth 2001). Once thought to be the academic pursuit of educators and child psychologists, early discussions about children's interaction with technology primarily appeared in academic books (e.g. Suppes 1969, Solomon 1979, Dwyer 1980, Papert 1980, Davis 1984), sporadic technology-oriented journal publications (e.g. Alpert and Bitzer 1970, Stodolsky 1970, Hunka 1973, Candy and Edmonds 1982), publications for educational researchers (e.g. Goldberg and Suppes 1972, Searle et al. 1974, Davis 1976, Lepper 1985), or conferences exploring educational issues (e.g. Feurzeig and Papert 1968, Papert 1972, Amarel and Swinton 1975, Solomon 1979, Hoyles 1985).

These early discussions focused on the impact that new technologies could have on children as learners. They also included discussions concerning educational theories that were explored or tested with the use of new technologies as tools for inquiry. With these understandings, researchers suggested new directions for future technology development, and new possibilities

for future learning experiences. During these early years, there were only rare instances where children had more direct involvement with technology developers, and actually tested experimental technology before it was in wide release. Interestingly enough, the development of programming languages such as *Logo* (Papert 1977) and *SmallTalk* (Goldberg 1984) involved children in the process more than any other technologies created during the 1970s and early 1980s.

In terms of the HCI community, one of the first conference paper publications concerning children and HCI issues was published at the 1982 Gaithersburg Conference that led to the establishment of SIGCHI and the annual CHI conferences (Malone 1982). This paper discussed a study that was done by Tom Malone (at the time from Xerox PARC) in which he analysed children's use of games. From his results, he proposed general HCI guidelines for designing enjoyable user interfaces. Malone's paper was the only one of 75 papers in the proceedings that discussed children as users. Subsequent conference papers on children and HCI issues were not common and would only sporadically appear in such conferences as Hypertext (Nielsen and Lyngbaek 1984), INTERACT'84 (Gulian et al. 1984) and CHI+GI'87 (Frye and Soloway 1987, Verburg et al. 1987). Interestingly enough, the paper presented by Fry and Soloway (1987) was entitled *Interface design: A neglected issue in educational software*.

Papers that discussed children and HCI issues would not significantly increase in number until the early 1990s (e.g. Pausch et al. 1992, Steiner and Moher 1992, Noirhomme-Fraiture et al. 1993, Berkovitz 1994, Strommen 1994). As the literature grew, so too it seems did the active involvement of children in the technology development process. Since the mid 1990s, children's roles as informants and design partners have been discussed in papers that have focused on everything from initial technology brainstorming experiences to final evaluation phases (e.g. Cypher and Smith 1995, Oosterholt et al. 1996, Druin et al. 1997, Inkpen et al. 1997, Scaife et al. 1997, Druin et al. 1999, Danesh et al. 2001, Ketola and Korhonen 2001).

Based upon an analysis of the literature and my own research experience with children, I have come to see four main roles that children can play in the technology design process: *user, tester, informant,* and *design partner* (see Figure 1). Each role has been defined based upon differences in how adults relate to children, what stage in the design process that children use technology, and what goals researchers may have for inquiry with children.

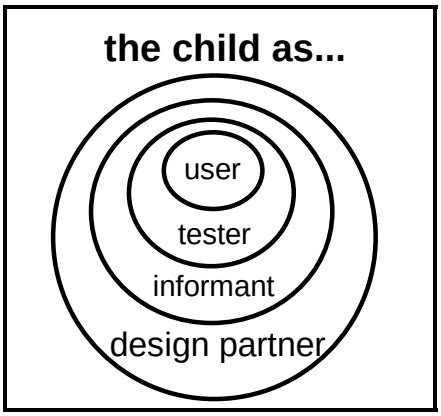

Figure 1: The four roles that children may have in the design of new technologies

To briefly summarize, in the role of *user*, children contribute to the research and development process by using technology, while adults may observe, videotape, or test for skills.

Researchers use this role to try to understand the impact existing technologies have on child users, so future technologies can be changed or future educational environments enhanced. In the role of *tester*, children test prototypes of technology that have not been released to the world by researchers or industry professionals. As a tester, children are again observed with the technology and/or asked for their direct comments concerning their experiences. These testing results are used to change the way future iterations of the pre-released technology are developed. In the role of *informant*, children play a part in the design process at various stages, based on when researchers believe children can inform the design process. Before any technology is developed, children may be observed with existing technologies, or they may be asked for input on design sketches or low-tech prototypes. Once the technology is developed, children may again offer input and feedback. And finally, with the role of *design partner*, children are considered to be equal stakeholders in the design of new technologies throughout the entire experience. As partners, children contribute to the process in ways that are appropriate for children and the process.

I have come to see that each role, *user, tester, informant,* or *design partner* can shape the technology design process and impact the technologies that are created. While each role for children is used today by some portion of researchers or developers, each role has its own historical roots with its own challenges and strengths. These roles are not necessarily different from the roles that adult users may take on, however the specific methods, context, and challenges can be very different in numerous important ways thanks to the involvement of children. The reasons behind why researchers may choose to use any of these roles with children can depend on the project's research or development goals, resources, timeframe, and the philosophy of the researchers involved. While each of these roles has clear differences, each role includes aspects of those roles that historically have come before it and therefore can be graphically represented as embedded ovals (see Figure 1). For example, in the role of informant, children may be asked to test certain prototypes (as a tester) as well as be observed with competing software (as a user).

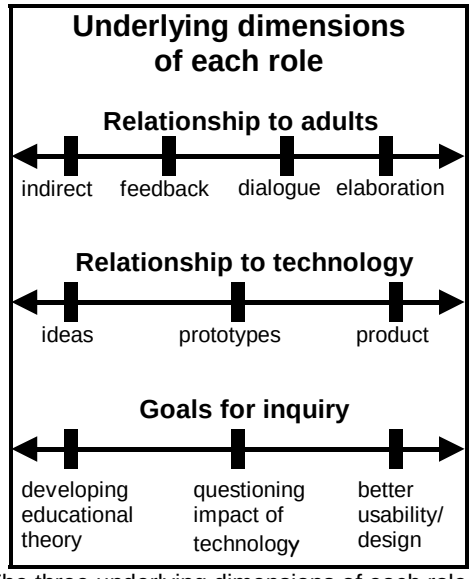

Figure 2: The three underlying dimensions of each role for children

Each of these roles will be discussed in this paper based on three underlying dimensions: (1) the relationship to adults; (2) the relationship to technology; and (3) the goals for inquiry (see Figure 2). Each of these dimensions has a continuum of possibilities that can define some aspect of each role. For example, in considering how children can relate to adults, children may communicate what they know by being observed and thereby offering indirect input. They may also offer direct verbal or written feedback on ideas or technology that adults have developed. Children may also engage in a dialogue with adults about design ideas that they themselves have instigated. In addition, children may elaborate or build upon another adult or child's ideas to develop something entirely new. One or many possibilities on this continuum may be true for each role. For example in the role of tester (see Table 1), children's relationship to adults can be through indirect observation or feedback; their relationship to technology can be in using prototypes; and the goals for inquiry may range from wanting to better understand usability and design issues, to exploring the educational impact of technology, to using technology as a tool for inquiry about a larger educational issue.

Role of child	**Relationship to adults**				**Relationship to tech**			**Goals for inquiry**		
	indirect	feedback	dialogue	elaborate	ideas	prototype	product	theory	impact	usability
User	**x**						**x**	**x**	**x**	
Tester	**x**	**x**				**x**		**x**	**x**	**x**
Informant	**x**	**x**	**x**		**x**	**x**	**x**		**x**	**x**
Design Partner	**x**	**x**	**x**	**x**	**x**	**x**	**x**			**x**

Table 1: A Comparison of the three dimensions for each role

The sections that follow will present a detailed analysis of each of the four roles in relation to these underlying dimensions. In doing so, the historical context of each role and the research methods needed for such a role will be discussed. Following this, strengths and challenges of these roles will be presented along with a final summary of the unique contributions children can make to the development process. While all four roles will be discussed in a somewhat similar manner, it should be noted that this paper was written by a researcher who is actively involved with children as design partners. Whatever biases and experiences I have had with children will no doubt colour my discussions. In particular, a more personal look at the role of design partner will be presented. However, I by no means wish to suggest that my approach to research is any better than any other. A goal of this paper is to situate my work within the context of others and in doing so gain a better understanding of all of these roles. I believe that if we can make more informed decisions about our design practises, then we can have lasting effects on future new technologies for children.

3 The child as user

The first and oldest role that can be seen in the literature is that of the *child as user* (see Figure 4). With this role, the child is a user of technology while the adult looks to understand the child's activities with various methods. Children may be observed, videotaped or tested before and/or after technology use. In this way, researchers can come to understand the impact technology has had on the child's learning experience. There are generally two reasons for researchers to ask children to take on the role of technology user: (1) To test a general concept that may help inform future technology developers (2) To better understand the process of learning which may contribute to future educational practises. With this role, the technology

used is not continually being developed and changed. The technology has been created and distributed widely for commercial or research purposes.

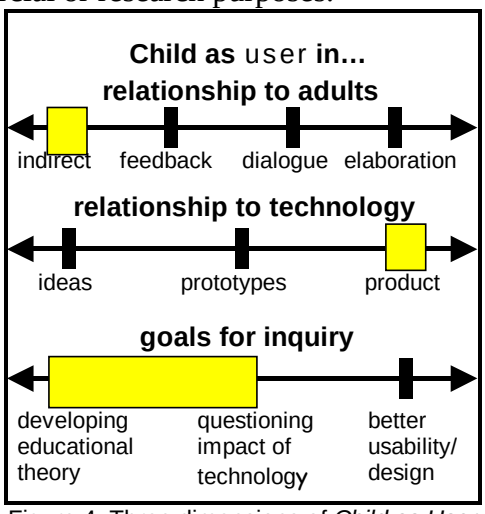

Figure 4: Three dimensions of *Child as User*

3.1 Historical context

The role of *child as user* is perhaps the oldest and today remains a common role for children in the research process. This role first emerged in publications, in the late 1960s and early 1970s (e.g. Suppes 1969, Stodolsky 1970, Hunka 1973). This was a time when mainframe computers were common, and educational applications were by and large 'drill and practice' experiences in everything from math to English. The computer was an individualized teacher and led a child through a series of carefully moderated exercises. The curriculum was broken down into small concept blocks with exercises that had different levels of difficulty. When the computer presented reading materials and questions to answer, the child was asked to respond (see Figure 5). If for example, a correct answer was given, the child was rewarded by being allowed to go to the next level of materials. If the child answered incorrectly, he/she was asked to try again (Suppes 1969, Davis 1976, Solomon 1986).

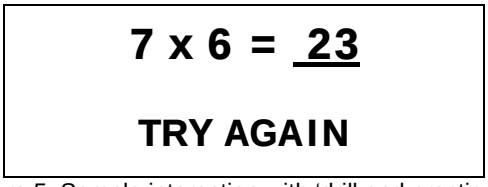

Figure 5: Sample interaction with 'drill and practice' experience

While these technologies automated the learning experience, they did not offer a great deal of control to the child learner and user. What was to be covered and how it was to be presented was pre-programmed by the computer system. In some sense, this lack of user control was also reflected in the limited involvement of the technology user in the development process. For example, according to researchers involved in Suppes' early drill and practice systems, 'The system content or style of delivery was never changed even though children were observed in those early years. What was updated were the mechanisms for collecting data and distributing it to the teachers' (Personal Correspondence April 22, 2000). At the time, interestingly enough, it

seemed that technologies were changed more to accommodate teacher and researcher needs, rather than children's needs as users.

In the 1960s and 1970s, the field of HCI did not yet exist and the first conferences were not until the early 1980s. But even in the early years of HCI conferences, papers still discussed users in regards to technology as not really knowing what they needed. In one paper that discussed a survey of 445 designers, 'almost nobody recommended that potential users become even for only brief periods of time, part of the design team' (Gould and Lewis 1983: 51). This can be strongly contrasted with the cooperative design movement that was emerging at the time from the Scandinavian countries, which promoted the notion of co-design with users (Bjerknes et al. 1987).

In terms of children as technology users, the majority of the literature during the 1970s and 1980s reflected their limited involvement in the technology design process (the few exceptions will be discussed in later sections). The terminology that was used to describe children's involvement, offers a glimpse into the role of users at that time. Such phrases as, 'the subject's task', 'allow the user', 'children should be used' were common and all suggest that users, especially children, had little control in the research process. The main contribution of children as users was seen in the observations that researchers could make of them, the work children accomplished using the technology, and the tests children took before and after using computers. These experiences could tell researchers more about the impact of technology. The role of child as user can still be seen today. It is more common in the literature of educational and child psychology, as well as the broader educational research community, but it still can be seen as a tool to consider the future of new technologies and new educational uses of technology.

3.2 Methods used

The research methods utilized when children are users in the technology design process vary depending on the information of interest, the size of the user population involved, the research philosophy, and the experience of the researchers involved. These methods may be quite similar to those of working with adults, however there is a need to adapt certain techniques for children's ages, cognitive and social abilities. In addition, the context of school (rather than the workplace) also necessitates changes to the methods used.

Typically researchers will use methods of observation to look for patterns of activity, and general user concern (e.g. Hunka 1973, Candy and Edmonds 1982, Neal and Simons 1983, Nicol 1988, Nielsen and Lyngbaek 1989, Burov 1991). This is particularly common for research with young children (ages 4 and younger) due to the limited communication and writing skills in children's early years. Methods of observation can be done using one-way mirrors or live television monitors. Video cameras can also be used to capture data for later analysis (e.g. Fell et al. 1994, Lester et al. 1997, Goldman-Segall 1998, Plowman et al. 1999). For example, in a study by researchers at the University of Sussex, the Open University, and the Scottish Council for Research in Education, video was used to record two forms of data: 'One (video camera) recorded the group of learners at the computer to capture talk, movement, gesture, and machine interaction; the other (captured) the screen image, taken from the computer via a scan converter. The videotapes were mixed in an editing suite, transcribed, and used for very detailed analysis of learners' talk and behaviour, and their path through the material' (Plowman et al. 1999: 314).

In addition to video, participant observation where researchers are in the room with users can also be of value (e.g. Nicol 1988, Pelegrino et al. 1991, Plowman 1992). It is common for researchers to become a part of classroom activities demonstrating software, answering

questions, and more. At the same time, it is quite common to include teachers in the research experience. They too can collect data thanks to their own first-hand experiences in the classroom (e.g. Rose et al. 1998, Koenemann et al. 1999). Children's use of the computer can also be captured and understood through system logs showing patterns of interaction with different system tools (e.g. Searle et al. 1974, Candy and Edmonds 1982, Neal and Simons 1983, Jackson et al. 1998). These methods were useful, for example, in understanding early hypermedia technologies with children. Researchers at Apple Computer observed children's reactions to HyperCard's menus and commands, as well as tracked their navigation patterns in various information spaces (Nicol 1988).

In addition to activity observation, data concerning user impressions can also be collected. Qualitative surveys can be given to children concerning their like, dislikes, difficulties, and interest areas. For instance, interviews can be conducted after the use of technology, which can help to clarify children's motivations and pinpoint specific reactions to particular content. More formal quantitative surveys can also be administered, where questions are answered on a numerical scale or with various options such as faces that frown or smile (e.g. Burov 1991, Lester et al. 1997, Salzman et al. 1999, Read and MacFarlane 2000). These kinds of surveys can be at times difficult to develop. The survey language needs to be age appropriate, and easily comprehensible. This can be somewhat difficult for young children who have not begun to read text or understand certain visual symbols or numbers.

Information can also be collected concerning the impact that technology has on the child's learning of a subject area. It is common for tests to be given to children before and after the use of technology over a period of time. Typically, these tests are quantifiable instruments concerning subject matter knowledge (e.g. spelling, math, science, etc.)(e.g. Hunka 1973, Searle et al. 1974, Candy and Edmonds 1982, Burov 1991, Salzman et al. 1999). In some cases, ethnographic or qualitative descriptions of children as technology users are done as well to capture data. In these case studies, a small number of children can be observed over an extended period of time (e.g. Solomon 1986, Plowman 1992, Blomberg et al. 1993). Data collection can also be done, by asking children to write or draw their thoughts in journals. In those cases, it still may be necessary for researchers to ask children to explain their journal contents, since children's written reflections can be quite abstract until the age of 8 or 9. Teachers and researchers may also write down their observations over time. Periodic interviews with children and teachers may also be conducted.

Finally, results of the children's work using the computer can be analysed as well. For example, researchers at the University of Michigan collected software models created by 9th grade students (age 15-16). These students used special software to build for example, models depicting environmental changes in streams or global warming. These software models were later collected and analysed by researchers to better understand the students' use of certain software tools (Jackson et al. 1998).

Many times researchers will collect information about users in multiple ways, so that results from one research method can explain another. For example, in the case of Vanderbilt University's researchers, they gave children an initial 'paper and pencil' test that measured problem-solving capability in mathematics. They then observed classes of teachers and students with the technology (Pelegrino et al. 1991). Afterwards, they again administered a similar test. What they found was that children's test scores rose considerably after their use of technology. Their classroom observations showed them why. What they saw was an active engagement with

the subject matter through the use of technology. In addition, they saw that students were able to understand and 'anchor' ideas about math in real world situations (Pelegrino et al. 1991).

Data collection like this can also be useful when comparing users and non-users of technology. Many early studies compared children who used computers with children that had never used the technology. The Vanderbilt researchers did just this with their study. Not only did they look for change in those children who used their technology, but also they compared those changes with children who did not use their technology. This exhaustive study followed over 1,300 children for over a year and offered numerous insights into the use and impact of the *Jasper Woodbury* technology (see Figure 6) (Pelegrino et al. 1991).

Figure 6: 'Get Out the Vote': Part of the Jasper Woodbury Series on Complex Trip Planning
Students must prepare plans to drive as many voters as possible to the polls on Election Day. Students must prioritise goals, identify strategies, organise data and develop algebraic shortcuts.
(http://peabody.vanderbilt.edu/projects/funded/jasper/)

When analysing the data collected in studying children as users of technology, again, there are numerous methodologies. Depending on the kind of information researchers are looking for, can dictate the ways data should be analysed. For example, some researchers look to see how fast a task can be done (e.g. Suppes 1969, Searle et al. 1974, Burov 1991, Fell et al. 1994) others look to see how many content questions can be answered after a child uses a piece of technology (e.g. Hunka 1973, Searle et al. 1974, Candy and Edmonds 1982, Burov 1991, Salzman et al. 1999). Still others try to understand changes over time in children's activities. Do they recognise their mother's voice faster (Fell et al. 1994)? Is their motion sickness reduced (Salzman et al. 1999)? In all cases, the research methods are used to understand the impact that technology has on the child user. From this understanding, future technologies may be changed or developed. In addition, these new insights can offer a better understanding of how children learn, which can lead to new theories for education and new teaching practises with technology.

4 The child as tester

A more recent role for children in the development process is that of *tester*. While it may seem similar to that of *user*, the underlying framework dimensions in relation to adults, technology, and goals for inquiry are different (as can be seen in Figure 7). With this role, children test prototypes of emerging technologies. The goal of this role is for children to help in shaping new technologies before these commercial products or research projects have been released to the world. With this involvement, children are a part of developing new technologies that can lead to future product directions and/or new educational theories. As a tester, children may be observed with technology, and the impact on children can be assessed. In addition, adults may ask for direct feedback from children by asking them such questions as, 'What features did you like?' 'What was too boring?' 'What was too hard?' It is important to note, that with this role,

adults have already accomplished the initial brainstorming and design phase. Children do not begin their role as tester until initial prototypes have been created.

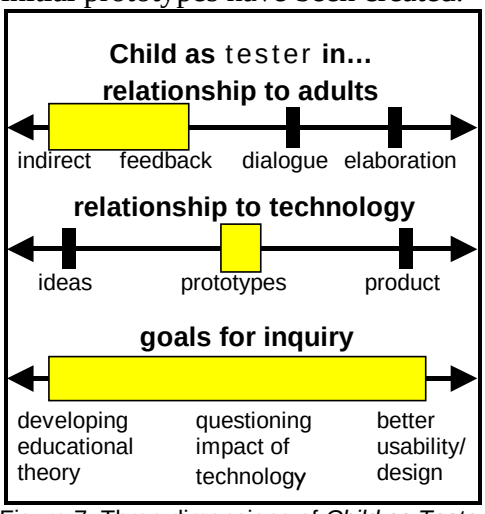

Figure 7: Three dimensions of *Child as Tester*

4.1 Historical context

The role of the child as *tester* was rare until the late 1980s and early 1990s. Before that time, only a few unique instances of child as tester could be found in the literature. Interestingly enough, these instances have come to be considered pioneering work in technologies for children. Today, there are few people focused on HCI and children, who do not know of Seymour Papert's research group at MIT. In the late 1960s and early 1970s, this group developed a new programming language for children that they called *Logo*. What is rather unique is that they also pioneered a new approach to teaching and learning with technology. They felt that the computer need not tell the child what to do, but the child could tell the computer what to do in ways that the child chose. In doing so, the child could construct his or her own paths to knowledge. This has since come to be called a 'constructivist' or 'constructionist' approach to using technology (Papert 1972, Hoyles 1985, Solomon 1986). Constructivism highlights the idea that children can be active constructors of knowledge, while constructionism suggests that one of the best ways for children to construct knowledge is by building it.

Generally, those researchers who work with children as testers are not as interested in exploring educational theories as they are in developing new technologies. But in the case of *Logo* researchers, their educational theories may have suggested new approaches to designing educational technologies, and their development of new technologies may have broadened their understanding of educational theories. It may well have been Papert and his colleagues' deeply held belief in children as builders, scientists, and learners that led to the early inclusion of children in the technology design process, much earlier on than most researchers of their time. Papert and his colleagues frequently point out in talks even today, of instances where children changed the way *Logo* researchers considered implementing a feature or where children found a problem that adults never saw (Solomon 1986). For example, when the *Logo* program was first developed, it was completely text-based. *Logo* programs could be created to manipulate words and sentences, but not images or graphics. Realising the need for more concrete objects to 'play' with, the *Logo* 'turtle' was developed (see Figure 8) (Papert 1980). According to Cynthia

Solomon, an early *Logo* researcher, 'We worked with kids between 1968 and 1969, and totally revised the language. As a result, we saw that we needed a better way for children to visualise their programming experiences and this led us around to the idea of the turtle' (Personal Correspondence April 28, 2000). Now going on 30 years, the *Logo* research team still works in a similar way: develop a working prototype, try it out with children and teachers, and then revise it based on input.

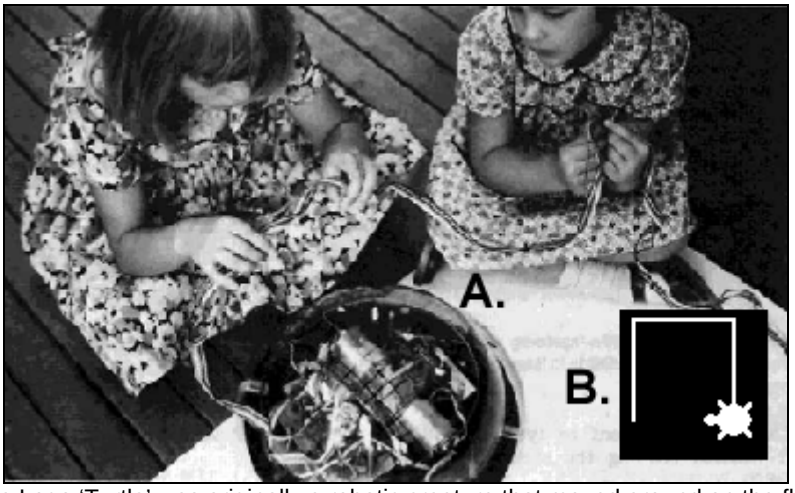

Figure 8: The Logo 'Turtle' was originally a robotic creature that moved around on the floor (A.) It later became a 'Screen Turtle' (B.) Both could be directed by typing Logo commands at the computer. (http://el.www.media.mit.edu/logo-foundation/logo/turtle.html)

While involving children as testers was a somewhat uncommon practice in the early 1970s, Papert and his team were not the only researchers at that time to involve children as testers. Alan Kay and Adel Goldberg, then at Xerox PARC, developed a programming language with children as testers (Goldberg 1984). This language was called *SmallTalk*. While this language was not expected to be used only by children, Alan Kay believed that children could offer powerful new insights for future new technologies (Solomon 1986).

It was not until the late 1980s and early 1990s, that children as testers were consistently reported in the literature. This coincided, not surprisingly, with a general trend in the HCI literature toward developing better interfaces for non-programming end-users. No longer was the HCI community primarily concerned with developing better interfaces for programming (Grudin 1990). By 1990, numerous papers and panels reflected this move toward embracing non-technical users and bringing them into the design process. *Participatory Design*, (Blomberg and Henderson 1990, Johnson et al. 1990, Montford et al. 1990) *Heuristic Evaluation* (Nielsen and Molich 1990) and *Contextual Design* (Wixon and Holtzblatt 1990) were all discussed in paper and panel sessions.

At that same time, researchers and industry professionals were beginning to discuss the child as tester in paper and journal publications. An early example of this was in the late 1980s, at the Bank Street College of Education where researchers were developing *Palenque*, an interactive multimedia environment based on the popular *Voyage of the Mimi* product (Wilson 1988). It enabled children to explore virtual multimedia worlds that included tropical rainforests, rivers, a temple, museum and palace. Children tested the technology's navigation tools, museum database of multimedia information, the appeal of the interface, and the comprehension of the

menus and icons (Wilson 1988). Continual feedback from children at the Bank Street School for Children, helped to shape and change this technology.

During the 1990s, the role of child as tester has come to be common in both industry and academia (e.g. Noirhomme-Fraiture et al. 1993, Berkovitz 1994, Strommen 1994, Moshell and Hughes 1996). Software products have been child-tested at companies such as Children's Television Workshop (Strommen 1994), Electronic Arts (Super et al. 1996), and Living Books (Druin and Solomon 1996). In addition, less common interactive plush animal interfaces have also been child-tested (e.g. Microsoft's Barney (Strommen 1998), MIT Media Lab's SAGE (Umaschi Bers et al. 1998). Today, it is a surprise, if children do *not* test commercial technology products.

4.2 Methods used

When children are included in the design process as testers, the methods used can be diverse. Similar to the methods previously described in the child as *user* section, researchers and industry professionals look to understand the child tester's activity patterns, likes/dislikes and changes in learning. However, with the role of child as *tester*, the reason for a child's involvement also includes help with design or usability issues for revision of prototypes. Therefore, the kinds of research or development questions may deal with more immediate issues: What parts of the technology are confusing that can be changed? What parts do children like so that new features can be added? Can children learn with the technology so it can be marketed as an educational product? Where are the bugs that need to be addressed before release?

The number of times that children and adults may attempt to answer these questions with test sessions can vary. In the case of the Living Books Company (now a part of Broderbund which is a subsidiary of The Learning Company) developers work with children after every few screens they develop. For example, with the CD-ROM title, *The Tortoise and the Hare* (see Figure 9), children let developers know that they were unhappy when they selected a particular hotspot (Druin and Solomon 1996). With this selection, the Hare would run out, read a newspaper, crumple it up, and leave it on the ground. Many children felt that the hare was littering. So designers added an additional hotspot animation. Today, with the resulting product, if children select the crumpled paper on the ground, the Tortoise says, 'Hey Hare, did you forget to recycle that paper?' (Druin and Solomon 1996).

Figure 9: From the Living Books CD-ROM, Tortoise and the Hare
(http://www.livingbooks.com)

Other product teams do not have the time or resources to work with children as often. In the case of Kid Pix, when it was first released back in 1989, Broderbund sponsored their first Kid's Day. It was a weekend testing day for 20 children to try out Kid Pix. Developers offered their testers cookies for a break and a crafts table with paper, glue, glitter, etc.—just in case the testers got bored. According to Broderbund employees, few cookies were eaten and almost none of the crafts were used. It was determined that Kid Pix would be a hit (Druin and Solomon 1996).

How focused or broad the testing activities are, depends on the needs of the product or project. There may be certain areas of the product that developers have questions or concerns about. Therefore, that particular area will be heavily tested. In the case of Microsoft's Actimates/Barney, developers wondered if it was all right for a child to be interrupted in a song or game if the child selected something else. Therefore, developers observed children with a Barney that could 'not be interrupted'. Through child-testing, they found that children became frustrated with Barney if they could not interrupt themselves and move on to another activity (Strommen 1998).

The number of children needed during the testing process can vary. If the prototype is still in its early stages, then a few children for a few hours can be all that is needed to spot the big problems. For example, at Northwestern University, researchers worked with six Middle School students (ages 12-14) to initially test the general functionality of the *Progress Portfolio* software (Loh et al. 1998). Thanks to these early observations of children using the software, researchers were able to pinpoint the need for additional work in the areas of capturing and annotating (Loh et al. 1998).

The number of children as testers may also be limited if the methods used offer large amounts of data. In the case of SAGE (Storytelling Agent Generation Environment) researchers were interested in better understanding how this stuffed-animal interface for storytelling (see Figure 10) could support seriously ill children (ages 7-16) in a cardiac unit of Boston's Children's Hospital (Umaschi Bers et al. 1998). With this understanding, researchers hoped to change SAGE for the future, and develop design recommendations that might be useful for future researchers working with this same user population in hospitals. The way they chose to answer their questions was to interpret the stories of eight children who used SAGE. Researchers looked at these stories to try to understand the roles that the child played when using the technology, what personality the child took on, and in what way the child symbolically represented him/herself in the story. With countless pages of data to read and analyse, eight children offered researchers the information they needed.

Figure 10: SAGE: Storyteller Agent Generation Environment
(http://marinau.www.media.mit.edu/people/marinau/Sage/index.html)

It is important to keep in mind that children's involvement as testers necessitates methods that can be done quickly due to product or research time-frames. Working in schools may not be as much an option as bringing children to the lab or workplace after school. The ever-continuing prototype revisions, and product cycles may not be as easy to integrate into the constraints of a busy school schedule and the requirements of already over-worked teachers. On the other hand, when children are users, school settings are more common as a context for research. How different are methods for testers when they are children as opposed to adults in this role? They

are somewhat similar, but due to children's cognitive and social skills, the role of children as testers may necessitate small changes in everything from interview style (e.g. less formal language) to activities to keep children busy while not being testers (e.g. crafts tables and cookies, rather than newspapers and sandwiches).

5 The child as informant

With this role, children play a part in informing the design process (see Figure 11). Before any technology is developed, children as *informants* may be observed with existing technologies, or they may be asked for input on paper sketches. Once the technology is developed, children may again offer input and feedback. With this role, children play a part in the design process at various stages, based on when researchers believe children can inform them. Therefore, the underlying dimensions of this role are more numerous when it comes to children's relationship to adults, technology, and goals for inquiry.

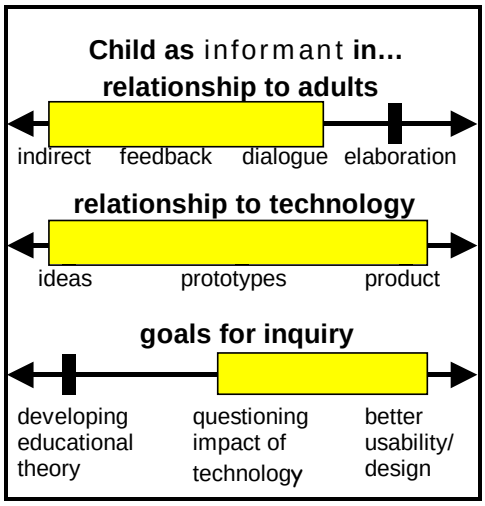

Figure 11: Three dimensions of *Child as Informant*

5.1 Historical context

The role of the *child as informant* did not emerge in the HCI literature until the middle of the 1990s. There was literature before this time that discussed children informing the design process, but primarily as users for observation or as testers of prototypes. Until the 1990s, children were not discussed as design participants who offered design directions, or prompted the start of new projects. Interestingly enough, the emergence of this informant role for children coincided with the establishment of a new CHI conference submission category called, 'Design Briefings'. This publication category focused on the methods of design, rather than the technology results. While these conference submissions were not just about the design process with children, they may have helped to bring to the attention of the HCI community the presence of children in the process (e.g. Halgren et al. 1995, Piernot et al. 1995, Oosterholt et al. 1996, Druin et al. 1997, Rader et al. 1997, Scaife et al. 1997). [Note-The category of Design Briefings has since been folded into the CHI paper submission options.]

From this point on, the design of children's technologies and the design processes used became frequent publication topics at HCI conferences. This timing also coincided with the growth of the multimedia industry worldwide. CD-ROM software titles were becoming financially lucrative and CD-ROMs were being sold as a standard component in most PCs.

According to the Software Publishers Association, over one billion dollars (US) of educational software was sold in 1994 (Investors Business Daily 1995). In all likelihood, children as informants were a part of the design process much earlier in HCI history, but adult researchers were not formally recognising their presence. For example, folklore could be heard among industry professionals that described how children shaped and changed design directions. Craig Hickman, creator of *Kid Pix* and Roger Wagner, creator of *HyperStudio*, were among those with stories to tell, but little was documented in academic journals or conference publications (Druin and Solomon 1996).

It wasn't until 1997 that the role of child as informant became more clearly defined. It was at that time that Scaife et al. presented *Designing for or designing with? Informant design for interactive learning experiences* (1997). In this critical publication, they described the notion of 'informant design'. The authors questioned when children should be a part of the design process, and what contributions could be important for the design of technology. Before this time, numerous researchers were including children in the design process, but not making a distinction of when. Were children testers at the end of the design process? Were children partners working throughout the process? Were children informants helping the design process at various critical times? Mike Scaife and Yvonne Rogers from University of Sussex continued to question these important notions in their follow-up publication, *Kids as informants: Telling us what we didn't know or confirming what we knew already* (1999). In this book chapter, they explained, 'What is not in doubt, then, is that children can be brought into the design process and make a contribution. What is less clear is whether we can generalise about the relationship that they can be expected to have with designers' (1999: 30).

Out of these critical discussions a clearer understanding of the child as informant began to emerge. As this role has come into sharper focus, both industry professionals and academic researchers have found it quite useful. An example of this informant role can be seen in the design of Knowledge Adventure's popular CD-ROM, *My First Encyclopedia*. This educational software for young children throws away the traditional interface elements of windows and menus, and instead uses a picture of a tall tree as an interface mechanism. By selecting any of the tree's branches, video guides support young users in finding information. This simple visual interface for an encyclopaedia was designed by a team led by Roger Holzberg. When this team began their work, Holzberg went to daycare centres and preschools looking for children's input. He asked children, 'Where do you most like to play after you go home from school or daycare?' Their most common replies were, (1) 'play outside' and (2) 'climb a tree' (Researcher Notes April 5, 1995, Telephone Interview with Roger Holzberg).

Therefore, thanks to the inspiration of children as informants, a tree was developed as an interface. Could Holzberg and his colleagues have developed a tree without the help of children? Perhaps, but with children suggesting directions at the very start of the design process, a tree quickly became obvious as an interface metaphor. Holzberg's experience is not unique. Many industry professionals or academic researchers have now come to acknowledge the role of children in setting directions for everything from new digital library interfaces (Wallace et al. 1998) to new programming languages for children (Smith and Cypher 1999).

5.2 Methods used

When and how children are informants varies a great deal between design teams. Some, as in the case of Knowledge Adventure, have an idea for a product, but are looking for an interface direction. Others, such as Allen Cypher and David Smith (1995, 1999) may wonder if their

initial project idea is even appropriate for elementary-school children. While still at Apple computer, Cypher and Smith asked the question—could children program their own interactive simulations? To begin to address this, the design team worked with fifth-grade children (ages 10-12) and asked them to 'program' a person around a room by placing 3M Post-It notes with programming instructions on their clothing. For each Post-It note, another command could be executed. The team learned that children could program these kinds of simulations, and that they might really like to do so (Cypher and Smith 1995). Since that time, a product first called *KidSim* and now called *StageCast Creator* has been developed, and the design team has established a company (http://www.stagecast.com).

There are numerous ways to bring children as informants into the design process. At the start of a project or product design, teams may decide to observe children using existing technologies. In this way, design directions may not necessarily be expressed directly by children, but may be implied by their actions. These methods of observation are similar to the ones outlined when children are users or testers. What differs from those methods is when these observations happen and how directly it can affect the design of new technology. In the case of researchers from the University of Michigan, they began their project by observing 6th and 9th grade students (ages 11-16 years old). They watched the students' use of web search engines and browsers while studying science (Wallace et al. 1998). From these observations, researchers became convinced that web tools were not sufficient for learners searching out information. The search engines returned too many hits, and students seemed to become bored. In response, the research team developed *Artemis* (see Figure 12) software that supports learning with digital information resources. This is now a part of the University of Michigan's Digital Library initiative.

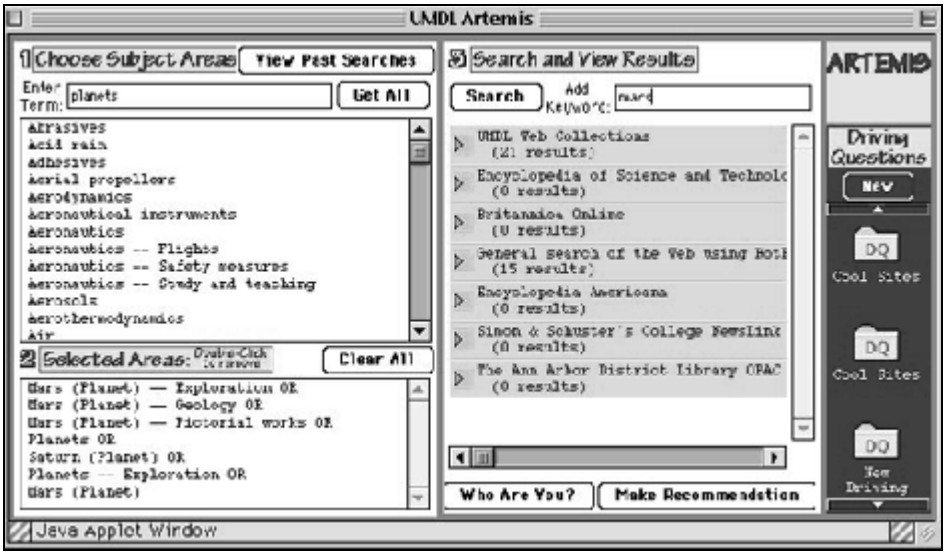

Figure 12: An example of the Artemis software that was developed at the University of Michigan (http://hi-ce.org/teacherworkroom/software/artemis/index.html)

Initial ideas or observations of children from the start of a project are not the only time children can inform the design process. They can be involved at any time the design team believes it needs direction or support. For example, Scaife and Rogers (1999) after realising a prototype they had developed was considered 'dull' by children, decided to probe further. To do so, they used low-tech sketching materials and artefacts. They asked the children to sketch

possibilities for software that could be used to teach other children about food webs. After minimal results from this method, the team gave laminated cut-outs of organisms to the children. The children manipulated these cut-outs and told researchers what could be done to make software. With this method, the children didn't get caught up in the details of drawing animals (as they had while sketching) and concentrated on the interaction and behaviours of the animals. What is clear is that if one method does not produce the information needed for design, teams must not be afraid to try something else quickly.

Low-tech materials, interviews, design feedback on prototypes, can all be used continually as methods for informants. It is critical however, that these materials and methods are age appropriate for working with children. Many of these methods are similar to previously described techniques for when children are in the role of user or tester. What differs is when and how often these techniques are used during the design process. Even the question of where the most appropriate place to work with children can vary. In many projects a combination of working in schools and in the lab can support a project where children are informants. There is no magical formula of what to do and when. However, what is certain, is that a design team can choose to include children as informants in various ways and at numerous times depending on the needs of the team and the specific project.

6 The child as design partner

The role of *child as design partner* is similar to that of an *informant*, however, as design partner children can be a part of the research and design process throughout the experience (see Figure 13). With this role, children are considered to be equal stakeholders in the design of new technologies. While children cannot do everything that an adult can do, as partners children can have an equal opportunity to contribute in any way that is appropriate for the design process. For example, adult researchers that are visual artists or educators can support the technology design process with domain specific expertise and experience. Each cannot do what the other does well. The same can be said of child researchers. They too have special experiences and viewpoints that can support the technology design process that other partners may not be capable of contributing (Druin 1999). With this role of design partner, the impact that technology has on children may not be as significant as the impact children can have on the technology design process. Therefore the goals for inquiry may be more limited, but the relationship to adults and technology are greatly expanded for children (see Figure 13).

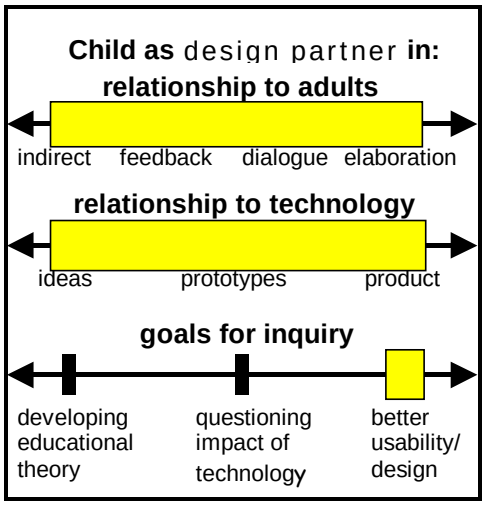

Figure 13: Three dimensions of *Child as Design Partner*

6.1 Historical context

We have a belief at the University of Maryland that partnering with users is an important way to understand what is needed in developing new technologies. This belief has been heavily influenced by research practises over the past 20 years: the *cooperative design* of Scandinavia (Bjerknes et al. 1987, Sundblad 1987, Greenbaum and Kyng 1991), the *participatory design* of the USA (Blomberg and Henderson 1990, Johnson et al. 1990, Greenbaum 1993, Schuler and Namioka 1993) and the *consensus participation* of England (Mumford and Henshall 1979). As Greenbaum and Kyng (1991) have explained, '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' (1991: ix-1).

This partnership between users and researchers from different disciplines was first exemplified in the Scandinavian 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 (Bjerknes et al. 1987, Sundblad 1987, Greenbaum and Kyng 1991, Schuler and Namioka 1993).

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. By the 1990s, these practises were being adapted and applied to research with children (PDC'96: Participatory Design Conference 1996, Druin et. al. 1997, Druin 1999, Benford et al. 2000, Danesh et al. 2001, Ketola and Korhonen 2001).

As an individual researcher, my methods with children first took root in an intellectual environment that embraced building technology for children in a constructivist model of education. In the early 1980s, at the MIT Media Lab, I was a part of a community of researchers that strongly felt children should construct their own paths to knowledge, and that computer tools

should support children as builders, designers, and researchers. It was a community that was grounded in years of developing *Logo* and *Smalltalk* programming languages for children. Yet, surprisingly enough, if you looked closely into the design practises of this community of researchers, it was not very common to find children as partners in developing those constructivist tools. Children were primarily testers, and adults came up with the great ideas.

It would take me almost five years to begin to understand the full extent of a design partner, why children could be partners, and how partnering could come about (Druin, 1999). It did not happen suddenly one day, but rather, these concepts and understandings evolved slowly over the years with numerous research and development experiences with children. Over time, I found that the more I worked closely with children, the more I came to expect the unexpected when it came to ideas, technology directions, and honest feedback from children. These experiences took on an importance for me. I saw myself as a researcher personally move from working with children as testers, to informants, to finally and firmly as design partners. In my early work at the MIT Media Lab as a Masters student developing NOOBIE, children tested ideas, offered suggestions, but I was clearly the one with the idea to build a 6-foot stuffed computer that replaced the keyboard and mouse with hugging and squeezing (Druin 1987). In my later work with children in New Mexico, children were clearly a part of the brainstorming process, but not continually (Druin et al. 1997). While I referred to them as my partners even then, it has now become clear that they were only a part of the design process more sporadically than continually. I have since come to realise this may have been due to my attempt to work in schools with strong structural constraints. I later discovered that establishing an after-school programme in my lab could offer more flexibility, time and resources for on-going partnerships.

Today, children are most definitely our partners in all that we do at the University of Maryland's Human-Computer Interaction Lab. Twice a week, children ages 7-11, join researchers from computer science, education, psychology, art, and robotics. Over the summer, the team meets for two intensive weeks eight hours a day to continue our work. Children have remained with our team as long as three years and as short as one year. Together we have become what I now call an 'Intergenerational Design Team' pursuing projects together, writing papers, and creating new technologies. This intergenerational design team has produced research projects that include digital libraries for children (Druin et al. 2001, Revelle et al. In Press), storytelling robots (Druin et al. 1999), collaborative zooming software for authoring (Benford et al. 2000, Boltman and Druin Submitted) and kits for designing room-sized storytelling environments (Alborzi et al. 2000, Montemayor et al. Submitted).

Design partnerships with children are not isolated to the University of Maryland. For example, researchers at Nokia Research Centre partnered with children to explore ideas for a ToyMobile (Ketola and Korhonen 2001). Children's participation ranged from low-tech prototyping to prototype feedback. Another example of partnering with children was at Hampshire College. A year-long partnership was established at a local Massachusetts elementary school with fifth-grade children (9-10 years old). Together they developed a CD-ROM that supported the exploration of fifth-grade math skills (Porteous 2000). The lead researcher from Hampshire College joined the University of Maryland team during the previous summer to learn design partnership methods and subsequently adapted and brought them to the school. The recent results of this team's work can be found at http://www.cs.umd.edu/~jessica/kidc.html.

Children as design partners also become a critical part of the research methodology in a three-year project funded by the European Union's i3 Experimental School Environment

initiatives (Benford et al. 2000, Taxen et al. 2001, Druin and Fast Submitted). Between 1998 and 2001, KidStory was a collaboration between almost 100 children and 25 adult researchers in Sweden and England whose goal was to develop new collaborative storytelling technologies for children (see Figure 14). Researchers at the Swedish Institute of Computer Science, the Royal Institute of Technology, Sweden, and the University of Nottingham collaborated with the University of Maryland in generalising our partnership methods with children. KidStory has now finished its third and final year, and we have seen how children as design partners impacted the technologies we developed. 573 design suggestions were collected from the children's journals that led to significant development efforts in designing new storytelling technologies (KidStory Deliverables August 2000).

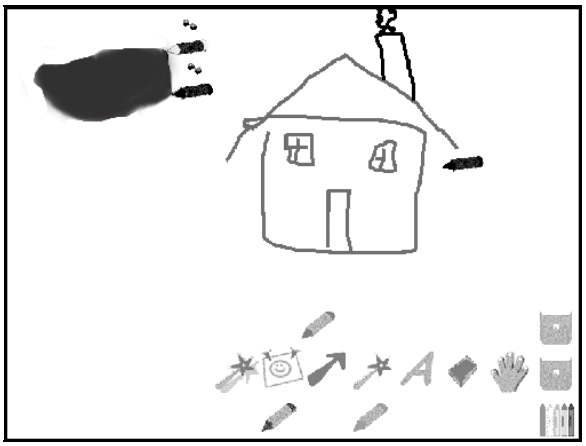

Figure 14: An example story being created in the KidPad collaborative software. This work is developed as a part of the KidStory research project in partnership with children in Sweden and England (http://www.kidpad.org)

6.2 Methods used

Over the years, we have found that the most important goal of a partnership between adults and children is 'idea elaboration'. This is when one team member (adult or child) shares an idea with the team. From this idea, a new thought or direction may be inspired by another adult or child. When these ideas build upon each other to create new ideas, ultimately it may be difficult to remember whose ideas they were originally. What matters is that both adults and children share in the process together. It can be said that this elaboration process is the hallmark of any good design team with or without children. However, what makes this so important to partnerships with children is that idea elaboration is so difficult to have with young people. What is more common is that adults conceive of ideas and either teach them to children, or ask for feedback from children. The notion of elaborating on each other's ideas is more difficult and therefore colours all that we do in our design partnership methods. To support the best circumstances for idea elaboration with children, our team has changed the way we set expectations, brainstorm, and reflect as a team. In the sections that follow, more description of those areas will be discussed.

setting expectations

We have found that expectations must be defined so that all team members can understand: (1) the roles that each play on the team, and (2) the day-to-day activities of the team. In regards to team member roles, we have found that it is hard for both children and adults to believe they are

truly partners. In general, we have found that both children and adults need time to negotiate a new 'power structure,' in which neither adults nor children are completely in charge (Druin and Fast Submitted). We have found that it can take up to 6 months for any team member to become a full partner in the experience (Alborzi et al. 2000). We try to keep in mind that 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. Children need to learn that their ideas are valuable and will be heard by adults. On the other hand adults need time to learn that children are no longer to be observed, but rather people to discuss and develop ideas in partnership.

We have developed a few practises that help to set expectations at the start of a team's work (see Table 2). These methods attempt to support a feeling of equality among team members. They are simple practises, but we have found them to be important in trying to change the existing power structures between children and adults. It should be noted that adults expect these practises as common cutesy, but children find these practises extremely difficult to carry out. Perhaps the most difficult two processes to carry out for children are *no raising hand*s and *use first names not last*. Both are habits that are not encouraged in children's school experiences.

Methods to set expectations	How this supports design partners
No raising hands	To change this accepted practise (commonly supported in schools) and bring about an equality among team members by enabling all to contribute without asking permission
Use first names not last	To minimize the distinction between adults (Mr., Ms., Dr.) and children without 'titles'
Wear informal clothing	To create an atmosphere that is supportive of working and frees adults from wearing clothes that may represent them as authority figures
All team members are paid (Children are paid in a yearly 'technology gift' due to child labour laws in the USA).	To show that all team members are valued for the work that they contribute. This also reminds children that this is not school where projects are made to be graded and not actually used in the real world.

Table 2: Methods to set expectations

We have also found that what helps in building respect for all team members is to quickly establish common goals and participate in collaborative design activities as soon as possible. In other words, instead of talking about design methods, children and adults quickly begin doing them. Younger children in particular are helped with some quick introductory design experiences, such as inventing a new sandwich, redesigning a new milk carton, and finding objects in their classroom to fix. In each case, children and adults work together in small groups to brainstorm and discuss 'what is wrong' with the existing 'technologies'. Teams might, for example, decide that the problem with a milk carton is that it is too difficult for young children to pour from, and therefore it needs to be redesigned so that children can't spill milk easily. We have had groups 'prototype' the perfect *spill-proof* milk carton out of plastic tubes, clay, and straws. (KidStory Research Notes, Class Session #8, Stockholm, Sweden, March 16, 1999). We have found, as children accept their role as inventors of what they know, they can better understand their role in evaluating and redesigning computer-related technologies, such as a new mouse or a piece of software (Druin 1999).

In addition to setting the general expectations of the role that each partner plays on a team, we are also careful to set team expectations at the start of any project, and at the start of any design session. The way we do this is with something as simple as 'snack time'. While this was meant originally to replenish the energies of young children and graduate students with food, we have come to see this time as a critical part of our design methodology.

Each of our sessions starts with 15 minutes of snack time, where adults and children informally discuss anything that comes to mind. One day it could be a discussion about too much homework in school, the next day it could be sharing the most embarrassing situation we've all ever encountered. We have found that when our team spends time this way, adults and children come to know each other as people with lives outside of the lab. This helps all partners to be more eager in later sharing ideas. The intercultural communications literature discusses this type of informal socializing in 'contact theory'. This theory suggests that to get beyond prejudice and develop better working relationships there must be some social contact (Jackson 1987).

Following this informal discussion, we typically talk about the work for the day. We look to find agreement among design team members when it comes to goals and activities to be accomplished

brainstorming

The specific brainstorming techniques we use have come to be called *cooperative inquiry* (Druin, 1999). These methods have evolved and developed over the last seven years. They began as methods for bringing *adult* users into the technology design process. Such methodologies as *contextual design* (Beyer and Holtzblatt 1998), *cooperative design* (Bjerknes et al. 1987), and *participatory design* (Greenbaum and Kyng 1991, Schuler and Namioka 1993) call for adults from different domains to partner with technologists during the technology design process. From brainstorming methods that ask users and designers to sketch out ideas (participatory or cooperative design) to interviewing methods that can capture user tasks, roles, and design ideas (contextual design), innovative research methods are being found to work with users. While these methodologies for adults offered an excellent beginning structure for our research with children, they needed to be adapted to suit a team that included children, for example, to overcome the teacher-student paradigm invoked by groups of older and younger researchers in favour of co-equal partnerships. Over the years, our note-taking practises, interview procedures, data analysis, and day-to-day team activities have evolved. For example, we have found that interviewing procedures for adults are not appropriate for speaking with children. We have since changed everything from what team members should use as notepads (small and inconspicuous) and how they should dress (informal), to the process of capturing and synthesizing data (Druin 1999).

We have found that no single technique 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*:

(1) Contextual inquiry: To observe what children do with what technologies they currently have. Younger children can have a difficult time abstractly discussing the world around them (Piaget 1971). Observation techniques specifically developed to understand children's exploratory activity patterns are used. This includes having adults observe children and having children observe children using technology. It is critical that children are as much a part of the data collection as adults.

When using contextual inquiry observation and note-taking, we often look for children outside of the team to observe, so that all team members (children and adults) have a chance to 'watch'. The note-taking techniques of adults and children obviously differ. But two techniques have been developed to suit the needs of adults and children. We have found that adults gather data effectively by writing short text descriptions of conversation and activities (see Table 2). On

the other hand, children seem to be effective in combining drawings with small amounts of text to create cartoon-like flow charts (see Figure 15). Once the adult notes have been compiled for a session, the adult notes are compared with the child notes. The adult notes are highlighted in the places that the child researchers have recorded in their notes. In this way, child and adult perspectives are captured. We have found that the child researcher summaries of the data, enable adult partners to see ideas they had originally overlooked (Druin 1999).

Besides comparing the adult and child notes, we also analyse the text descriptions of the adults (see Table 3). We begin by analysing the quotes and activities for *activity patterns*. By this we mean experiences children have repeatedly during a session. After identifying these patterns of activity, we are able then to identify the *roles* that children take on as they use different technologies (Note: these roles are not the same roles described in this paper, but the roles of technology use—e.g. child as storyteller, collaborator, leader). Lastly, we look at all of the previous information and formulate design suggestions that can lead to further development of project work.

RAW DATA:			DATA ANALYSIS:		
Time	**Quotes**	**Activities**	**Activity Patterns**	**Roles**	**Design Ideas**
0932	F: No, you're only erasing all the time. Lena, stop!		Struggling for Ownership	Leader	*Make ownership options*
	L: [To adult:] Can you help me, I'm trying to draw a circle. F: I know how to!	Asks adult to help her	Seeks help	Learner	*Help option*
0935	L: Hello, I want to move it here! F: Get the red instead!	L. is taking the mouse from F, puts the tools back again by help of the box	Struggling for control of input device	Leader	*Multiple input devices and/or collaborative software tools*
	F: But! L: There! F: Now you really have to stop!	L. takes the hand, takes the yellow crayon, draws a curve	Drawing	Artist Leader	
0945	L: Not a head! F: What do you want, then? L: A sun!	F. takes the mouse, rubs everything away	Struggling for control of input device	Leader	*Multiple input devices and/or collaborative software tools*

Table 3: Portion of a contextual inquiry diagram created by adults observing two 7 year-old children in a School in Sweden, 1999

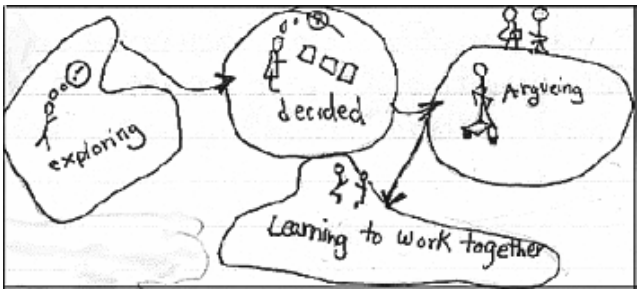

Figure 15: Contextual inquiry notes by a 7-year old child in the USA, 1998

(2) Participatory design: To hear what children have to say directly by collaborating on the development of 'low tech' prototypes. In addition to collecting data through observation, we have found that there is a need to hear from children directly (Druin et al. 1997, Druin 1999). Participatory design techniques can enhance what we have come to understand from observation. This does not mean that participatory design must follow contextual inquiry. However, we have found that contextual inquiry enables us to first explore numerous ideas through observation. Then, during our data visualization, we 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 collaborate with technology. This insight was taken into a participatory design session where low-tech materials were used to prototype collaborative storytelling technologies for the future (e.g. see Figure 16). In these participatory design sessions, small groups of three to four children with two to three adults create low-tech prototypes out of paper, clay, glue, crayons, etc. The low-tech tools give equal footing to adults and children. We have found that there is rarely a need to teach people how to prototype, since using basic art supplies comes naturally to the youngest and oldest design partners. The low-tech prototypes that are developed support the brainstorming and idea generation stage of the design process. This form of prototyping is inexpensive, yet quite effective in quickly brainstorming new ideas or directions. It is from these low-tech prototypes that high-tech prototypes emerge.

Figure 16: An example of a 'low-tech prototype' for a new storytelling technology. The design team explained that you can tell a story by talking through the straw/microphone. Feathers on the machine tickle you and make you laugh at the story. You can look into the machine's eyes to see the story going on. In addition, the machine can fly to other places to re-tell and collect other stories (KidStory Researcher Notes, Nottingham, England, November, 1998).

(3) Technology immersion: To observe what children do with extraordinary amounts of technology (similar to what they might have in the future). This process came out of our need to understand how children can use large amounts of technology over a concentrated period of time (Druin et al. 1997). We have found that if children are only observed with the technology resources they currently have, then what they might do in the future with better circumstances could be missed. 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 expect these limitations to change. Therefore, by establishing today a

technology-rich, time-intensive environment for children, the observation techniques of contextual inquiry can be used to capture many of the activity patterns that perhaps might be over-looked in lesser circumstances. With technology immersion, it is critical that children not only have access to technology intensively, but are also supported as decision-makers in this technology environment. All too often, we are only able to glimpse what children do with technology, and those activities are heavily influenced by what adults say they must be. Instead, there must be the freedom for children to accomplish a task that is meaningful for them. Without these ingredients, it is difficult to understand children's technology wants or needs. Technology immersion experiences can be as large as a CHIkids programme at the annual CHI conferences (in 1998, 60+ children and 25+ adults participated) or it can be as small as a camp-like experience for six children and four adults in our own labs (Druin 1999).

team reflections

We have found that team design with children can be especially 'messy'. Unfortunately, it can be easy to lose track of ideas or data generated by the team. This may be due to a quick change necessary in the brainstorming process that day. This may be due to a young child's inability to remember where he or she left the team notes. This may also be due to an adult forgetting to hit the 'record' button on the video camera, because a child team member interrupted him in the middle of a thought. Therefore, we use a combination of journal writing, video camera observation, team discussion, and adult debriefing. With many ways to capture data, we are less likely to lose what we are looking for (Alborzi 2000).

In terms of journal writing, children and adults are asked to keep a 'lab notebook' that can include anything from what they found important one day, to making a list of things they still need to do for a project. We use these journals to keep track of our project ideas, and to examine the design process—what's working, what's not. We find that children will tend to draw their reflections while adults will tend to write. Because of this, it is critical that children are asked to talk about what they have drawn so that adults can annotate their drawings. In addition to the journals, in each design session we use video to record our activities. For the most part, the children on the team will use the video camera. In this way, our young team members feel less self-conscious about a camera since one of their own peers is using it. In addition, the adults on the team also feel less uncomfortable being taped since it is likely a child is videotaping the oddest of things (e.g. a knee, a nose, room fly-thrus, etc.).

Team reflection also occurs with a great deal of discussion. Many times we will split up into smaller groups to accomplish a series of tasks needed for a day. When this happens, we are sure to end the day with a full team discussion about what each sub-group accomplished, thought about, or found. Following each design session, we also have an 'adult debriefing'. This is a time when the adults on the team reflect on the design process. How are we doing? What new or better ways are there to help the children understand a difficult concept? This is a time where adults can stand back and look at the big picture of things—sometimes more difficult to do when children are present.

Another critically important way we reflect on the technologies is to ask *other* children to test what we have made. We have found that it is not enough to get the opinions of seven children in creating a technology. They are our design partners and have developed a deeper understanding of a particular technology than a typical child user. Therefore, we also work with children as *informants*. For example, on our digital libraries research we work in a local elementary school with 100 children 7-9 years old in 2nd and 3rd grades (Druin et al. 2001). We see the design

partner children in our lab as having a critical role in the initial brainstorming experiences that set directions for our research explorations. On the other hand, we see the children in our partner school as informants in helping us to understand if our ideas are generalisable among a diverse population of children. What we recently found from working with our informants is that the initial digital library prototypes we developed, actually helped children search a library of animal images more efficiently by age and gender in comparison to searching with paper (Revelle et al. In Press).

Overall, the reflection process is critical in capturing design history, refocusing efforts if necessary, and evaluating what we have made as a team. Reflecting can help us to set expectations and change our team brainstorming practises as well as help us to revise our new technologies.

7 Challenges of each role

When children are *users*, *testers*, *informants* or *design partners*, there are inherent challenges to supporting these roles in the design of new technologies. These challenges are not ones that only adult researchers or developers must face, but there are challenges for the children in these roles, and the teachers that may also be involved. In the sections that follow these challenges will be discussed.

7.1 Challenges of the child's role for the adult researcher or developer

Bringing a child into the design process, whether they be in the role of *tester*, *informant*, or *design partner* is challenging for adults, simply due to what children will tell adults. Children are incredibly honest and at times harsh in their assessments of technology. Children have little patience for what they don't like and they will let adults know exactly just that. Even researchers can have their feelings hurt when they hear a child say they don't like a piece of technology that took months or years to create. If children are not a part of the initial brainstorming process, then they may offer some serious surprises, particularly when they are in the role of *testers*. While this research information can ultimately make a successful product or project, it can also derail a development schedule with some surprising results. A team must decide how 'much' they can afford to listen to what they have just heard.

Another challenge for adults is in knowing when the right time is to bring children into the design process. For some, resources are at a minimum so it is hard to justify to management that the additional expense and time is necessary. If however, researchers or developers wait until the product is released, then the results of their work with children are limited to offering suggestions for future projects. However, the earlier children are brought into the design process the more time and money that is needed to accomplish technology design. There is no question, working with children slows down the process, but the information they bring to the design process can be critical. Therefore, adult designers must weigh the needs of the project to make the best decision for them.

A challenge that is unique to working with children in the role of design partner, is that adults are not in charge, but neither are children. Design partners must negotiate team decisions. This is no easy task when children are accustomed to following what adults say, and adults are accustomed to being in charge. Methods of communication, collaboration, and partnership must be developed that can accommodate children and adults. Due to this unique challenge, the

development process can take more time than with other roles. If tight deadlines are looming, this can be very difficult on a team.

Another important challenge when working as design partners with children is in overcoming the difficulty of finding researchers or industry professionals who want to work with children as partners. With computer scientists, artists, and many other disciplinary professionals, the patience, experience, or desire to work with children may not be the reasons why they went into their respective professions. Therefore, team members need to be selected that can enjoy the 'messiness', noise, and unconventional research activities this kind of collaboration can bring.

7.2 Challenges of the child's role for the teacher

For teachers, whenever a design team wants to work in the classroom there are challenges to overcome. No matter how simple the research methods or design activities are, teacher involvement is still needed. Class times may need to be changed to accommodate the testing or design activities. Teachers may be asked to spend their own time contributing to the data collection process. In today's schools, where a national curriculum and mandated testing are common, little time can be afforded for such outside research activities. Spending class time on testing new technology rather than learning spelling, may be difficult to justify.

When children are asked to be informants or design partners as a part of the classroom experience, these roles may be particularly challenging. These roles necessitate more time spent with the children than if they are to be users or testers. Thanks to the flexibility of these roles, there may be times when researchers are not in the classrooms. There may also be other times that researchers are in the classrooms continually. This research flexibility may be problematic to structure given the limitations of the school day.

In addition, particularly in the case of design partnering, certain activities may go against the norm of the school culture. Not having children call teachers by their last name, or doing away with hand-raising, might bring about behaviour that is not conducive to other parts of the school day. Researchers may assume that educators have been trained to do this kind of work, but they have been taught to 'teach' not 'partner' with children, and therefore, old habits must be challenged.

It should be remembered that anything a design team chooses to accomplish in the classroom affects teachers. They are accountable to parents and principals for what gets taught and how their children behave. Therefore, unless a teacher sees some important value in what a team has to offer, they will be hard-pressed to agree to the work involved.

7.3 Challenges for children in these roles

The challenge for children in regards to almost all of these roles (except for *design partner*) is that ultimately adults are still in charge. Adults have to decide when to work with children, how to work with them, and ultimately what they choose to hear from children. Particularly in the role of *user*, children are watched or tested, and they do not initiate changes in research techniques. More traditional research methods of surveys and written tests can also be difficult or stressful for young children to negotiate. They may be frustrated with the lack of control or uninterested in the activities. For example, in the Vanderbilt University study (Pelegrino et al. 1991), researchers reported that, 'Assessments were often less pleasant and informative for students and teachers than hoped' (McGilly 1995: 76). In other words, the data collection experience of testing was something that students and even teachers found difficult. Researchers

need to keep this in mind when designing ways to understand the impact technology has on children.

Besides the actual methods for research, children may have challenges with the actual technologies they are using, testing or helping to inform. Ultimately in those cases adults have the first say in what will be created before children ever become a part of the process. Therefore, once children have an opportunity to suggest changes, there is a chance that these changes may never get made, since it is ultimately up to adults to make those changes. If adults don't agree with the feedback, or if adults decide that the changes are less important then getting the product out the door—changes just won't happen. Children can feel frustrated and disappointed in the process, which can lead in the future to uncooperative users, testers, or informants.

On the other hand, while children may feel more empowered with being design partners, this too can present challenges. If children are to be an on-going part of a design team that is not located in a school, then parents must take on the burden of transportation as well. This necessitates time and energy, which many of today's families have little.

In addition, the challenge of an on-going partnership with children must also be considered. No longer are children only a part of the research activities for a day, or a month. On-going years of collaboration, means at a very young age, a commitment to research team activities that can infringe on a child's after school time.

8 The strengths of each role

While there are clearly many challenges associated with each role for children, there are also many strengths that each role brings. These strengths will be described again in relation to adult researchers, teachers, and children that may be involved.

8.1 Strengths of the child's role for the adult researcher or developer

When children agree to take on certain roles, research can be accomplished somewhat efficiently. For example, when the child is in the role of *user*, the methods offer adults some semblance of control when defining the research activities. Children are told to do one activity and then the next. Once these activities are completed the research can be analysed and conclusions can be drawn. When a child is in the role of *tester*, extraordinary amounts of time may not be needed to find initial results. For researchers or product developers on a tight schedule or budget, this can be an important consideration. A one-day workshop for children to work with researchers can be offered at the lab or in a school. After-school programmes can be developed that need little teacher involvement. Depending on the kind of technology that is being tested, school complexities may be kept to a minimum.

For researchers, when a child is in the role of *informant*, there can be flexibility in when and where activities take place. In some cases, it may be more appropriate for children to work in schools. At other times, the university lab or industry offices may be more suitable. Schedules can be worked around for teachers and researchers, since there will be various times that it is not necessary to work with children.

A unique strength of the *design partnering* experience is that there is little waiting to find out what direction to pursue. Feedback and discussion are available on a weekly basis (sometime daily basis depending on the time of year). This offers a great deal of flexibility for development activities. If researchers know that children will always be available at certain times, then less formal schedules need to be made.

Finally, a benefit of using any of the roles is that adults can come to better understand children. No matter the limitations, these roles can enable adults and children to answer research questions or develop exciting new technologies for children. Thanks to children's input it may ultimately change the way we use technologies for teaching and learning.

8.2 Strengths of the child's role for teachers

A benefit for teachers when the research or design process comes to their classroom is that their teaching practises can be informed by what they learn. For example when researchers analysed over 1,300 students (8-12 year old) during the 1990-1991 school year, classroom educators felt comfortable with the striking results that showed technology helped children learn (Pelegrino et al. 1991). Results such as these can start to make changes in the classroom. Teachers can begin to integrate new technologies in their classroom in ways reflected by the research. An example of this is a teacher we worked with in the UK. In the project's second year, she won a national award for her teaching practise after the judges observed her work with technology in the classroom (KidStory Deliverables August 2000).

When teachers are an active part of the design process, this too can be empowering. In both our KidStory research in Europe and our Digital Libraries research in the USA, teachers have come to realise that they too can have an impact on how technologies are changed. For example one Maryland teacher wrote, 'I can't believe how exciting this all is. I get to see the software change and grow. It's like watching one of the kids I teach. I'm really proud of what we're doing' (Teacher Journal September 2000). We have also seen when teachers are design partners in particular, the team activities are strongly supported by the school since teachers feel a sense of ownership. Finally, when teachers have their classroom of children involved in the technology design process, it can also mean more usable technologies for many other teachers and classrooms to use in the future.

8.3 Strengths of each role for children

The strength of involving children as *users*, *testers*, *informants*, or *design partners* is that they can feel empowered. Each offers a different degree of empowerment, but children can feel that adults want to listen to what they have to say about new technologies. Children have so few experiences in their lives where they can contribute their opinions and see that they are taken seriously by adults. We have found that design partnering for children can build confidence in children academically and socially. It can also produce what we have come to call 'design-centered learning' (Druin 1999, Druin and Fast Submitted). In analysing our Swedish child design partners' journals, we saw that over three years, 20 out of 27 children (ages 5-7) changed from being learners and critics, to being inventers and design partners. We have seen that children and adults can experience changes over time due to their partnership and common design goals. Children can grow to see themselves as something more than users of technology. They can come to believe that they make a difference. As Jack, one our 9-year old child design partners explained, 'It will be a new millennium and we can change lots of stuff. We want to change stuff over our lives. Grownups need to know what kids are asking for' (Researcher Notes, April 22, 2000).

Children can also learn more about working with other people, and become more aware of their communication and collaboration skills. In the case of Alex age 8, he explained, 'You have to be patient with them, since they only know what adults know. But when we are patient you can learn from adults and they will learn too. We all need to talk together and listen together.

Sometimes people have to remember to hear first and then talk' (Researcher Notes, April 22, 2000).

9 The contributions of children

> *Let me argue, that the actual dawn of user interface design first happened when computer designers finally noticed, not just that end-users had functioning minds, but that a better understanding of how these minds worked, would completely shift the paradigm of interaction* (Kay 1990: 58).

What Alan Kay suggests is that users can make a difference, something that the HCI community has come to understand. But the question for those of us working with children, is how can children make a difference? In other words, what are children best at contributing to the technology design process?

In analysing these four roles for children, we may wonder if there are ever inappropriate roles for children in the design process. Are there roles that children should not be asked to consider? This can be answered by asking if there are ever inappropriate roles for artists, or educators, or even computer scientists in the design of new technology. I believe the answer is yes. If we ask people to be something that they cannot be, then it is inappropriate. If we do not take advantage of all that an artist or a teacher or a musician can offer the design process, then it is also wrong. I believe the same can be said for children. We must understand what children have to offer at different ages, and understand what that can mean for the design team process. We cannot expect very young children to program as well as computer scientists. We cannot expect them to know what educational goals need to be covered in a school curriculum as a well as a teacher does. But we can expect children to tell us what excites and bores them, what helps them learn, and what can be used in their homes or schools. We can expect children to be creative, honest collaborators. Children can also help us adults to think beyond the traditional needs of the workplace. Instead of productivity, efficiency, or cost saving, they can help adults think about tools that can let people laugh, enable creativity, and support collaborative learning. (These are all things for adult technology too, but somehow it's more allowed when the tools are for kids.) Children can also contribute to the design process in actually helping to build what we all dream about. We have found children can solder, sketch interfaces, and even program bits of technology when we least expect it. But perhaps most importantly, children are very good at asking 'Why not?' They force us adults to keep questioning. While children have little patience for boredom, they do have what seems like infinite amounts of energy when they are engaged and motivated in a project—which can thankfully be contagious for adults.

Therefore, in summary, children can contribute to the technology design process in many valuable ways. What is critical is that we as adults understand why we choose the methods we do in working with children. It can make a difference in what we do in designing new technologies for children. In the future, we can look forward to greater challenges given the proliferation of new technologies and new more demanding users that are young people. We have a chance to change technology, but more importantly we have a chance to change the life of a child. Every time a new technology enables a child to do something they never dreamed of, it offers new possibilities for the future.

Author's bionote

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