The Child as Learner, Critic, Inventor, and Technology Design Partner: An Analysis of Three Years of Swedish Student Journals

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Abstract
From autumn 1998 to spring 2001, 27 Swedish children (14, at age 5 and 13 at age 7) partnered with researchers supported by the European Union[1] to create new storytelling technologies for children. After each of the many design activities, children were asked to reflect with drawings and/or writing in a bound paper journal. As the project concluded in year three, the children's journals were analyzed and four constructs emerged from the data: learner, critic, inventor, and technology design partner. This study examines the motivation for such a research and learning experience, describes the changes in roles we saw represented in our child partners' journals, and suggests possible future directions for educators and technology developers.

Keywords
critic, early childhood, design partner, inventor, learner, participatory design, technology innovation

1.0 Children as Inventors
Jerome Bruner, curriculum theorist and Harvard professor once wrote:

> *What a scientist does at his desk or in his lab, what a literary critic does in reading a poem, are of the same order as what anybody does when he is engaged in like activities—if he is to achieve understanding. The difference is the degree, not in kind. The school boy learning physics is a physicist and it is easier for him to learn physics behaving like a physicist than doing something else* (Bruner, 1960, p.72).

Today, educational theorists emphasize learning models that support active construction of knowledge and skills by each student. Educators and researchers have moved from supporting environments for passive assimilation of isolated facts, to advocating ones in which the learner actively explores the world: adapting, refining, and elaborating internal models of understanding (Eisner, 1994; Department of Education, 1995; Harel & Papert, 1990; Papert, 1980; Report to the President, 1997; Ringstaff et al., 1993; Sandholtz et al., 1990; Vygotsky, 1978). As Marton and Booth (1997) have explained, learning is a process of exploring what is already known and moving to what is unknown. Children need to understand that their existing knowledge can help them to learn that which they don't know. Educational researchers recognize that getting to "be" a scientist, poet, or artist is an important component of that learning experience (Cooper & Brna, 2000; Dewey, 1902; Dewey, 1936; Gardner, 1983; Harel & Papert, 1990; Shneiderman, 1998).

[1] i3, Experimental Schools Environment project # 29310

When we began our research with children as inventors of new technologies, we not only considered our work an opportunity for children to potentially learn, but an opportunity to make better technologies for children. What we adults have come to find out is that children have a lot to teach us particularly about the creation of new technologies for children (Druin, 1999b; Scaife & Rogers, 1999). In the sections that follow, children as inventors will be discussed based on a review of the literature in regards to how children's invention experiences can support learning and how children's involvement in invention can instigate the development of new technologies. Following this, a discussion of our own research with children as inventors will be presented in relation to a three-year European Union-funded project we call "KidStory". The results of our work with children will be described as it is reflected in the journals each child kept as an inventor over the three years of the research. We will also describe the changes in roles we saw in our child inventors and partners and again support our findings with examples from the children's journal drawings, writing, and discussion relating to the journals.

1.1 How invention supports children's learning

National curriculum standards have long stressed the importance of scientific inquiry, reasoning, observation, iterative design, testing, and analysis (e.g., American Association for the Advancement of Sciences, 1993; Department of Education, 1995; National Science Education Standards, 1996). The Swedish Curriculum for the Compulsary school stresses: "The student must believe himself capable of thinking … " (p 33) and "… the student must acquire the kind of knowledge he needs to solve concrete problems in his own surrounding" (p 34). Over the years, researchers have found that the process of invention in the classroom can strengthen children's problem-solving skills (e.g., Fields, 1987; Hudson, 1994; Lewis, 2000; McCormick et al., 1994; Spoehr, 1995), help in learning subject matter curriculum (Blumenfeld et al., 1991; Finegold & Pundak, 1991; Kafai & Yarnall, 1996) and teach necessary technical skills (Atkinson, 2000; Harel, 1991; Kafai, 1997). In recent years, researchers have looked at how the use of technology by children can support young people as inventors of children's technologies/software (Harel, 1991; Kafai, 1999; Druin, 1999b). As Yasimine Kafai, a professor in UCLA's College of Education has pointed out, when children are inventors, they move from being consumers to producers of new technologies (Kafai et al., 1997). This is consistent with the literature that suggests that children should be offered learning opportunities to construct their own paths to knowledge, something researchers have come to call "constructivist" learning theory (Papert, 1980; Harel & Papert, 1990). In the Swedish Preschool recommendations for new curriculum development, it suggests: "When children are constructing their own environment with the use of different materials they develop an understanding of a number of fundamental functions. To understand the proportions of a room, it is fundamental to understand mathematics and physics" (p 43). The purpose is not to teach children to become extraordinary scientific experts, but to engage, excite, and compel them to learn among other things about science, math, language arts, communication, and even teamwork while using the tools of technology.

One high school teacher who teaches robotics to his students in California described their learning experience this way:

> *Robotics motivates students to make plans, to accomplish, to look forward, to achieve and to feel good about themselves, in some cases for the first time in their lives. The*

robotics class itself is set up to allow students to feel comfortable with the new and sometimes very complicated concepts that robotics brings with it. To build an autonomous robot, students must learn the basic concepts of mechanics, engineering and "Interactive C" computer programming. They must also learn the skills of effective communication, teamwork and problem solving (Miller & Stein, 2000).

Professor Priscilla Norton, a teacher educator at George Mason University who focuses on integrating technology in schools, has explained, "A problem-centered curriculum in the disciplines places a solution to a real-world problem of interest at the center of the learning experience….Students' ability to solve the problem, to present their solution, and to revise their solutions in light of additional information becomes the goals. Placing the problem at the center emphasizes the students' doing rather than their mastery of discrete pieces of information and skills" (Norton, 1992).

1.2 How child invention can support the development of new technologies

In recent years, a growing awareness of the power of children as consumers has come to light. According to one study, it is believed that in 1999, teens influenced household purchasing decisions as much as $200-$500 billion US (Colkin, February 12, 2001). Another study estimates that even young children between the ages of four and 12 years of age have as much as $190 billion US in purchase influence (Sifton, December 1999). This coupled with expectations that children may become the fastest growing market in new wireless technologies (Colkin, February 12, 2001), has adults very interested in what children have to say about technologies. As futurist, Douglas Rushkoff has written,

Rather than focusing on how we, as adults should inform our children's activities with educational tidbits for their better development, let's appreciate the national adaptive skills demonstrated by our kids and look to them for answers to some of our own problems in adapting to post modernity. Kids are our test sample—our advance scouts. They are already the things we must become (Rushkoff, 1996).

Researchers have come to see that children possess certain abilities that can help in solving real-world problems for adults as well as children. Invention activities for children need not be limited to classroom exercises that can demonstrate certain competencies. In recent years, demonstration projects in the scientific community have shown children to be researchers in everything from biology to earth sciences, to technology development. For example, in the Tom Sawyer Project, 8-10 year old elementary school students worked with Hofstra University researcher Marty Condon to identify new species of fruit flies (McQuiston, 1995). Under a grant from the National Science Foundation, numerous new species were identifies and later reported in such journals as *Systematic Entomology* and the *Journal of Conservation Biology*. Dr. Condon explained, "As a scientist, you're trained not to see certain things, not to look in places where you've never found useful information. There's a real advantage to opening things up to people who don't have those kinds of preconceptions (McQuiston, 1995, p. A10).

Another pivotal example that has since been a model for other technology-infused learning experiences was the National Geographic KidsNetwork, developed by the Technical Education Research Center (TERC). Children were asked to be environmental scientists in measuring such things as acid rain or water pollutants in their environment (Julyan, 1993). They collaborated using technology to share their data with other student scientists as well as an adult mentor. With this learning experience, children contributed to their own scientific knowledge and the local community's understanding of environmental issues (Tinker, 1993). What researchers found was that the scientific data that children were collecting was so important that the children testified to the United States Congress in 1992 on such environmental concerns as acid rain (Tinker, 1993).

In recent years, numerous methodologies have been developed that bring technology users into the development process. Users have been described as active partners (Bjerknes et al., 1987; Bodker et al., 2000; Schuler & Namioka, 1993), inspectors or testers (Nielsen & Mack, 1994), or research participants to be observed and/or interviewed (Beyer & Holtzblatt, 1998; Erickson & Stull, 1998). With user input, technology can be shaped and changed in ways that may be meaningful for such users in the future. While user involvement is well understood as important to the technology research and development process, users that are children are less commonly involved than adults. When children's input is sought out, it is typically done so over short periods of time (e.g., a day, a few weeks, perhaps a few months). Children are most frequently asked to be technology testers in short intensive workshops or school settings (e.g., Loh, et al., 1998; Oosterholt, et al., 1996). However, researchers are beginning to understand the limitations of what children can contribute in these situations (Druin, 1999a; Scaife & Rogers, 1999). At the University of Maryland, researchers have developed numerous technologies with children as design partners (Druin, 1999b). From digital libraries for children (Druin et al., 2001) to storytelling robots (Druin et al, 1999), to whole rooms that can be interactive storytelling experiences (Alborzi et al., 2000), twice a week after school and two weeks over the summer, children and adults work together to develop new technologies in partnership. As Jack, one 9-year old child design partner 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). In the case of Alex age 8, he explained adults in this way, "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).

2.0 The KidStory Project

This section will examine the context in which our research study took place. It will describe the participants in the research as well as the school system they came from. Following this, a discussion of our research activities throughout the three years of journal writing will be presented.

2.1 Background

The KidStory project [kidstory.org] was a three-year project funded by the European Union's i^3 Experimental School Environments initiative. Its aim was to work with children as design partners to create collaborative storytelling technology. One of our research interests was to understand the extent to which partnership with children could be possible in a school setting, by inviting complete classes of children to participate. We worked with the two elementary schools: one in Nottingham, UK and one in Rågsved just outside of Stockholm, Sweden. It was evident from the very start of the research that the project worked in two very diverse environments. While our goals remained the same in each school, the way in which we achieved these aims differed due to cultural differences such as teaching methods, class structure and ideologies concerning assessment. The focus of this paper is the research we accomplished with the children and teachers in the elementary school in Sweden.

This Swedish elementary school is situated in a suburb approximately 10 km south of downtown Stockholm. It is a suburb of Stockholm with a large immigrant population. 98% of the housing in consists of low-income rentals and approximately 50% of the students have a first language other than Swedish. The school was built and opened in 1965. The school consists of 450 students and approximately 45 teachers. The students are between the ages 6 and 16. The classes for preschool and grade 1-6 consist of mixed age groups. Grades 7 to 9 work in homogeneous age groups. The school is surrounded by six nursery schools that support approximately 350 children, ages 1 through 5. Although the school and the nursery schools have different management, administrators actively collaborated within school projects. The National Swedish Curriculum that these schools followed is very general and states goals more than procedures. The curriculum for the elementary school was revised in 1994 and continues to be used today. Essentially, the goals are formulated as skills and knowledge expected from students after the 5th and after the 9th (last) year. Since January 1999 there has also been a pedagogical curriculum for the nursery school. Compulsory school begins in Sweden the year the child turns seven. In Sweden, there is only one intake per year and that happens in August. Traditional grading of all students (MVG=very well pass, VG=well pass, G=pass, U=fail) does not happen until age 14 (year 8).

Over the three years, our project worked with two classrooms of children: 14 children who began the project as 5 year olds and are now 7 years of age, and 13 children who began the project as 7 year olds and are now 9 years of age. Three teachers were also active participants in the project research. Researchers came to the school once every two weeks for a day and the activities were, for the most part, led by the researchers with the children and teachers participating.

The focus in regards to technology development changed over the three years. In the first year of research, the focus was to refine existing pieces of technology to support storytelling experiences in the classroom. During the second year, new and innovative storytelling objects were developed, and the work of the third year was to integrate the technology from the first two years into a creative augmented storytelling space or room.

2.2 Methods we used with children

2.2.1 The journal - a way to work, think and learn

At the beginning of the project, the children were given a journal, a large (30 x 42 cm) black book containing white pages without lines (see Figure 1). After every session the children drew and/or wrote their thoughts in the journals. The younger children were helped to write. The older children discussed what they had written. The reasons behind using journals in our research process are similar to why portfolios are used in the classroom. A portfolio is a “purposeful collection of student work that exhibits to the student (and others) the students’ efforts, progress, or achievement in a given area or areas”

(Los Angeles County Office of Education, 1997). The use of a portfolio in an educational setting can be used for the following reasons: to make sense of a child's work; to let others know about a child's work, and to relate the work to a larger context (Elmin, 1999; Kostelnik et al., 1999). Researchers have recommended portfolios as a method for integrating learning and assessment (Quesada, 2000; Schrock, 2000). In addition, research has shown that students can be motivated by the use of portfolios (Becker & Welch, 2000; Clemmons et al., 1993).

Figure 1: Children's journals

Within the KidStory Research project, we saw journals as supporting our work in multiple ways. From the standpoint of the children, they were able to reflect on their research activities by collecting their thoughts with crayon and pen drawings, digital photographs, and at times written words. The content in the journals helped the children to understand not only *what* they were thinking, but also *how* they were thinking. The journals were also supportive of self-assessment when children read what they had worked on. The children could follow their own process. We also saw many instances when the journals were supportive of language development. Most of the children in the project were bilingual. The text in the journals was written in Swedish but were their own thoughts. Like many other educators (Ashton Warner, 1972; Freire 1977; Leimar 1974) we found this very supportive in developing the children's reading skills. The children loved to read their journals for adults and school friends. We also found that the teachers and adult researchers in the project used the journals to assess their teaching and research activities.

In addition to the use of the journals in the classroom, they were also used in various ways to communicate the activities of the KidStory research project. From European Union conferences in Barcelona, Sienna and Helsinki, to end-of-the-year school fairs for parents, the children's journals have told the story of our research partnership with children. The journals were also included in magazine publications discussing the project (e.g., Fast & Kjellin, 2000)

Figure 2: An example "sandwich"

2.2.2 From a sandwich to a storytelling room: Project activities over the 3 years

When children act as if they are inventors, they are learning to invent. This is how we understood Bruner's words (1960, p 72), quoted at the beginning of this paper. In our research, we wanted children to feel as if they were truly inventors. Because these students were young, just 5 and 7 years old, we felt we had to be extremely concrete in our invention activities. The children needed an understanding of what an inventor was by working with something very close to their "zone of proximal development" (Vygotsky, 1962). Therefore, the children began their invention activities by being asked to invent a new sandwich. With the use of clay and coloured paper, the children invented fanciful new sandwiches. Beside tomatoes, pepper and salad there were houses, trees and snails on the top of the sandwich (see Figure 2). A few weeks later the teachers and the children prepared real sandwiches with the inventions as models.

To begin to understand the life of an inventor the children were presented with information about inventors in the literature. From this, the children were then asked to invent something that needed to be fixed from their surroundings. They invented for example, new spill-proof milk cartons.

To help strengthen the children's problem-solving skills (Fields, 1987; Hudson, 1994; Spoor, 1995) they were presented with a situation where something had to be invented to solve the problem. There was for example, a problem with "grandfather's chicken who one day got so scared of a dog that he jumped up in a tree and there he sat without being able to get down" (Researcher Notes, March 1999)

The children collaborated to develop a solution and numerous ideas emerged. These included:

> Måns[2] (age 7): *Grandfather takes a rope with a stone bound at the end. He throws the rope over the branch where the chicken is and grandfather goes up in the tree and can take the chicken. Grandmother comes with a ladder*. (see Figure 3)
>
> Johan (age 5): *A robot takes down the chicken*.
>
> Jonas (age 7): *You record the sounds of a hen or a rooster. And then you put the recorder in a cage. You take a long stick and put the cage close to the chicken and play the sounds. Then hopefully the chicken goes into the cage.*

[2] All children are identified only by their first names for research purposes.
The KidStory research project has permission to publish their work related to the research.

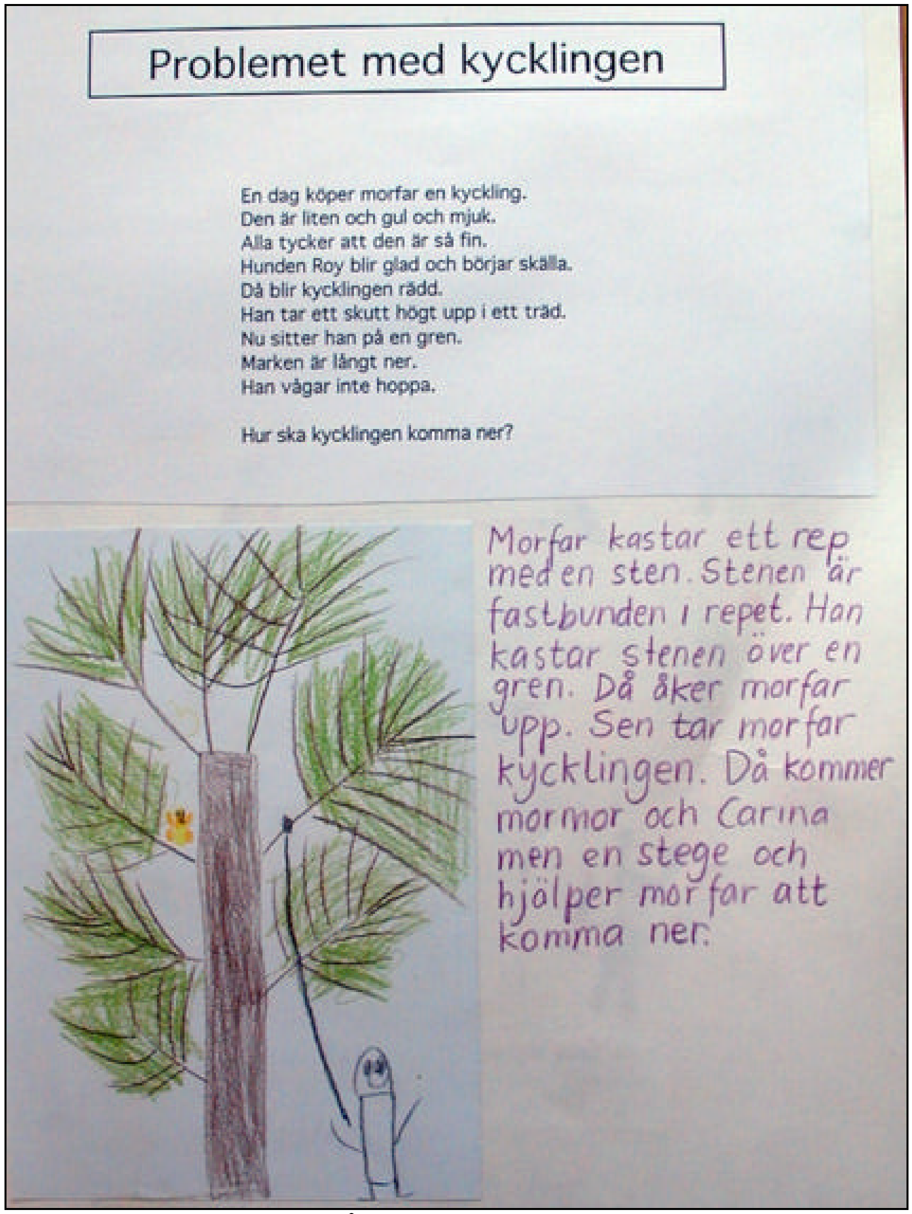

Figure 3: The solution that Måns had for bringing down Grandfather's chicken

During the second year of our research, new tangible storytelling technologies were created by our team. What occupied the children during the autumn was inventing "storytelling machines". The work started when the children and a teacher talked about what a story is. "When can you listen to stories?" There were many suggestions from the children. One young inventor had an idea; if you had a storytelling machine perhaps you could "step inside the story or build something which could help you to travel to the country of stories" (Researcher Notes, September 1999). The children and the adults started planning for such machines. They began this by sketching their ideas using simple art supplies (e.g., paper, clay, paste and pipe cleaners) to create "low-tech prototypes" (see Figure 4). We call this participatory design and this has become a central method to our research (Benford et al., 2000; Druin, 1999).

At the same time the children were drawing and writing about their machines in their journals. For example, such ideas included:

> Rahma (age 8): *In our machine there is a magic sofa. If you sit in the sofa you can travel where ever you want into a story*.
>
> Erik, (age 6): *We have different flags in our machine. If you take the flag from Turkey you can listen to a story in Turkish. If you take the flag from Greece you can listen to the story in Greek.*
>
> Henry (age 8 years): *We have different sticks in our machine when pulling them you can listen to different stories. The white stick gives stories from the past: The blue one is horror stories. The red one is love stories and the orange one is summer stories*. (see Figure 5).

Figure 4: Henry's example storytelling machine

One particularly interesting idea (see Figure 5) came from Fatima's journal, (age 8):

> *I have made a story dice.*
> *On the sides there is a forest, a car, Little Red Riding Hood, a cat and a boat.*
> *The drawings are different stories.*
> *You can throw the dice and there will be a story.*
> *You can change dice with another child and get her dice with her stories.*

Figure 5: Fatima's story dice

The dice metaphor is an example of a tangible storytelling object that the technical developers on our team used to create a true interactive prototype. The dice were 30x30 cm and had a drawing on each side. On each of these sides was also an RFTag that was "readable" by an RF reader. With the help of this tag system the children recorded sounds that went with the story drawing. The technology model was presented to the children who used and evaluated it.

> Johan (age 6): *I think the dice was boring it was not enough sound*

> Yalda (age 8): *I liked the dice very much but I want them smaller, I would like to have them in my pocket*.

During the third year, a few specific technology inventions from the two earlier years were integrated into a storytelling room where children could author and experience stories. The children created a background scenario, characters and props in digital form (by drawing on a touchscreen or using an ordinary mouse). It was possible to link sounds to the different story objects. The children also linked physical objects (whatever they wanted such as soft animals, drawings etc.) to the virtual objects. When the children told their stories they used the physical objects together with the virtual objects on the wall and the sounds. Again children reflected in their journals on the technology experience.

> Jonas (age 9): *Johan and I created a story about an elk and a nesting box. It was very fun. We would like to combine KidPad with the dice. You can record sounds on the dice and use it together with the pictures we draw on the wall with KidPad. But I wish I could draw straight lines with KidPad. I never manage.*

3.0 Examples of Design-Centered Learning

In the section that follows, we will define the constructs that emerged in our research experience. To us these constructs define, in a sense, the type of learning that occurred, the child's belief in whether there was a partnership, and the type of design activities the child was most able to do. Following a definition of constructs, examples of these constructs will be presented. This section will conclude with the results of our journal analysis.

3.1 Constructs that emerged from our research: learner, critic, inventor, design partner

In our work with children, we have found that their roles seemed to change in the project. Thanks to our qualitative analysis of their journals over the three years, we have seen four roles emerge from the data as constructs in their development as design partners: "Learner," "Critic," "Inventor," and "Design Partner." We define the *learner* construct as when children show in their journals that they are absorbing, understanding, and making sense of the process of invention. Their focus is in exploring the domain of invention as a classroom exercise. The construct of *critic* can be defined as when children show in their journals that they are recognizing what is good and bad in inventions around them. They can make suggestions for change in something that exists. The construct of *inventor* we define when children show in their journals that they are suggesting new ideas to be invented that have not necessarily been thought of in a particular way before. Many times, with this construct, children have an expectation that the research team can actually invent their new ideas. And finally, the construct of *design partner* is when children show in their journals that they can work with others in the invention process, whether it be adults or other children, in a collaborative way. We have come to understand that the role of design partner is a very challenging one for children. Many times they see the adults in the project as teachers or parents, but not partners in developing new technologies. Therefore, children in the project may defer to an adult as opposed to question, elaborate or build on the other's ideas. It was our research interest to see if any of our children could show signs in their journals of the design partner construct, and if so how many.

We understand that other researchers have analyzed the work of children's problem-solving and have developed similar but different constructs. For example, Killons and Todnem (1991) divided their students reflective thoughts into three constructs: "Reflection-on-action," "Reflection-in-action," and "Reflection-for-action." They defined *Reflection-on-action* to mean that the child looks at a work, already done, and considers, "Am I proud of my work? Did I learn something I didn't know before?" They defined *Reflection-in-action* to mean that the child reflects during the work by asking questions which include: "What am I doing? What am I thinking now? Why is it in this way?" That means that the child can change the way he/she works. They defined *Reflecting-for-action* to mean that the child looks at something already done and is thinking of what to bring next to the work. In some sense, this construct is most closely suggests our constructs of *critic* and perhaps the beginnings of *inventor*.

In the sections that follow we will give examples of our findings from the journals, which exemplify the constructs of leaner, critic, inventor, and design partner.

3.2 Our findings from the journals

3.2.1 Examples from journals that represent each construct

Learner

The best examples we have of the learner construct come out of the journals in the first year. During that time, the children may have been inventing sandwiches (see Figure 3), or ways to save a chicken (see Figure 4), but these experiences were all for the purpose of learning. They were not real-world situations, but more fanciful in nature. They were exercises for the children to learn what inventors do to solve problems.

An important use of the journals in the project has been to help the children to follow themselves as learners. We do know however, that reflecting on one's own learning is difficult and needs scaffolding to make happen. At the end of our first year of research, the children were asked in an interview, what they had learned by working in the project. We found that the youngest children (at that time 6 years old) found it very difficult to answer this question. Most of them answered, "I don't know." The 8 year-old children answered in more varying ways. Some of them said: "I have learned to think". And some of them said that they had learned to invent. Caroline answered that she had learned to use the computer much more and to speak English. Those children were not trained to think about their own learning. What we found was that the journals could help the children with the reflection process as something to elaborate on in their reflective discussions.

For example, at the end of our third year, we asked the children again, what they had learned, this time while again looking through their journals and we received the following responses:

> Yalda (age 9): *I have learned a lot, of reading, writing and I'm much better at drawing now. It's good to have the journal because you can remember what you have done and you can go on to invent out from old things. I want to save the journal all my life and show it to my children. I wish I could show it to my grandmother but she lives in Afganistan.*
>
> Eric (age 7): *I have learned to be an inventor. The book is so beautiful. I will think of it when I´ve gone to bed and then I can think what I can do in the same way at home.*
>
> Fatima (age 9): *My journal is like a brain office. There are a lot of small boxes and in all boxes there are thoughts we have thought about KidStory and I can go there and open the box and look and I can see what I have learned and I can tell my children when I grow up.*

Critic

In the second and third years we saw many examples of the critic construct. The children wrote or drew what they thought was good or bad about a particular technology. With this construct, children weren't necessarily solving what was wrong with the technology, but were expressing their opinion about what could be changed or what was good about it.

> Suaad (age 6): *I think the sofa was very good because when you are sitting there you can listen to birds who are whistling.*

> Eric (age 6): *The Klump is boring. The Klump is just disappearing, just disappearing.*

> Suraya (age 8): *I liked the camera very much because you could take photos of yourself and put it inside the KidPad program* (see Figure 6).

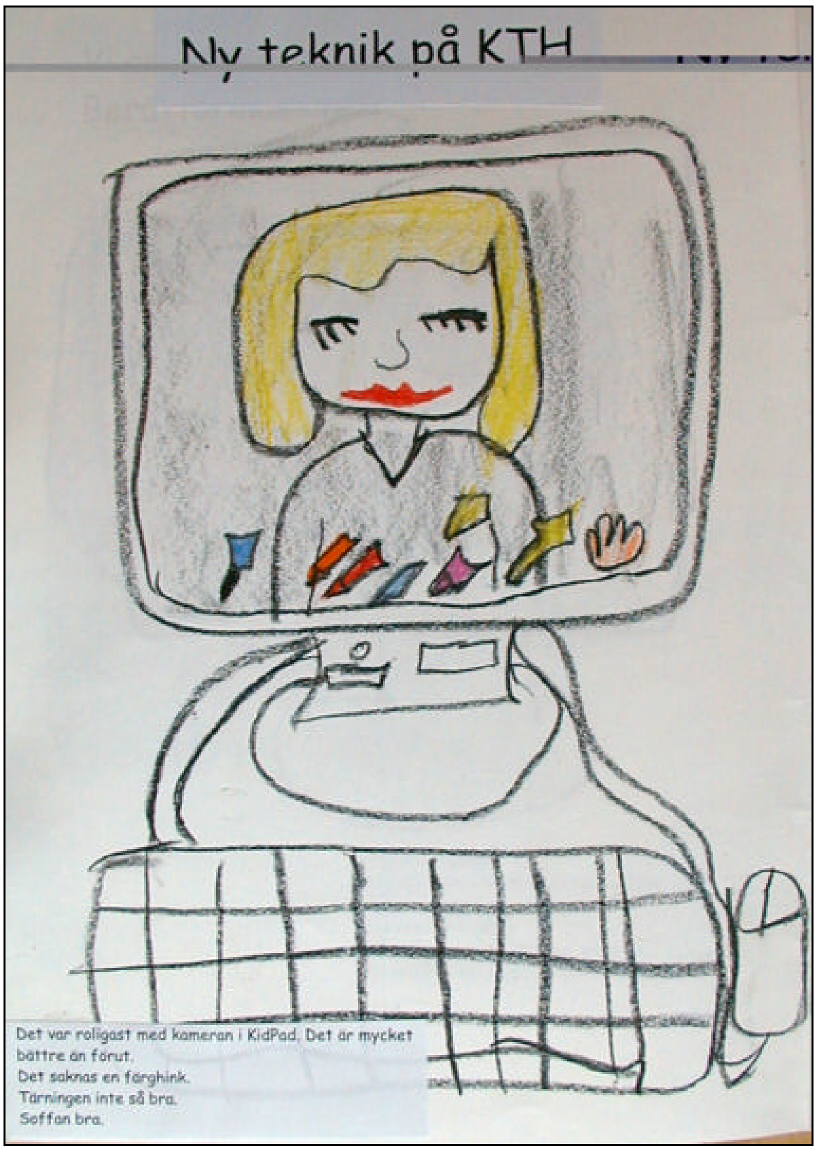

Figure 6: Suraya' comments about the camera she tested when visiting the university researchers

We have found children in the design process to be quite honest. Sometimes that can mean children's feedback can be quite negative and at times extreme. For example, after working with The Klump, a new software application that enabled children to design three-dimensional shapes, we asked the children about their thoughts.

> Researcher: How was it to work with the Klump today?
> *Child: Not so good.*
> R: Not so good? Why?
> *C: The arrow. It just went away. It happened … Many things happened. I want it to work. (Rearcher Notes, October 1999)*

We did see that many times the children were very constructive with their critiquing suggestions. For example:

> Researcher: Is there something you would like to change?
>
> *Child: I would like to be able to save things better. (Rearcher Notes,October 1999)*

In the first few years of the research, a great deal of critiquing was done on some of the project's technologies. Thanks to these criticisms we found 222 suggestions for change, which ranged from wanting more pre-drawn objects to tell stories with, to wanting more colors and easier ways to fill that color into spaces, to wanting sound integrated into the software (Taxen et al., 2001).

Inventor

During the three years, the children's journals have been filled with ideas about possible new inventions (see Figure 7). These inventions involved storytelling, since that was the goal of the KidStory project, to invent new storytelling technologies for children. Some examples from the journals included:

- Children wanted to be able to move to different places inside the stories with the help of *magic sofas, footsteps, a magic necklace, magic wand*.
- They wanted to be able to listen to different stories by pulling a *stick*, by showing different *flags*, by pressing different buttons, by opening a *story sack*.
- They also wanted to go inside the picture themselves and navigate by leaning to the right or left or by gestures or sounds.
- The children also invented human-like machines with ears, mouths, eyes and noses.


Figure 7: An example invention of “Magic Footsteps” that take you to story places

Design Partner

The difference between being an inventor and design partner has to do with the collaborative nature of being a design partner. To be a design partner is to collaborate and build on each other’s ideas. This is a difficult construct to show in the journals without knowing the context for the children’s journal ideas. In the example below, Yalda (age 9) reflects about her design partner experience in her journal after the session of the day:

> *It was so fun to create stories today when everyone was allowed to participate. I feel more happy when everyone participates. I had more fun today than usual. The dog was very sweet. The group was good. There wasn’t just one who decided everything.*

Another example of the design partner experience came from a group of 3 children and 2 adults. This team built on all of the technologies that were invented by the second year of the KidStory project to develop and present a physical immersive storytelling experience. They called it *Little Brown Riding Hood*. Together the team developed a storyline, selected the technologies that would be needed to get their story across, and designed the images and recorded the sounds for the story experience. For example, when a child who was supposed to be Little Brown Riding Hood, walked over one part of the floor, a forest was projected on the wall. There was a doormat on the floor and when the girl stepped on it, a door was projected on the wall with the use of RFTags under the doormat. There was also a doorbell on the wall and when Little Brown Riding Hood pressed the doorbell there was a drawing projected that looked like the inside of grandmother’s house. In their journals children described their design partner experience with words and pictures.

3.2.2 Children's changes between constructs

The children's journals were analyzed by two researchers who were actively involved in all three years of the school activities. The journals were reviewed separately and then discussed in a meeting by the two researchers. The journals were coded for the four constructs we discussed in the previous sections of this paper. These constructs were first developed by doing a preliminary analysis of the journals. The constructs were then refined, and used in analyzing the journals to see when clusters of constructs occurred for each child. Based on the predominate number and type of constructs at the end of each year, the child was suggested to be either a learner, critic, inventor, or design partner (See Figures 9-12). It was not unusual for example, to see one child's journal show examples of learner for an extended period of time, and then gradually show more and more instances of inventor. It should be noted that the first year's journals were found to show only the learner construct (see Figure 9). We believe this came about thanks to the research study's need to teach the children what research and invention was about during that first year.

In our analysis, we found that out of 27 children, 20 children changed over the course of 3 years, while 7 did not. Of the 7 that did not change, only 2 were among the older children and 5 the younger children. Of the children 20 children that did change, these children displayed an average of 2 constructs over the three years. Overall, we saw in the journals 10 children change from learner to design partner over the three years. Of those children, 4 began the KidStory research at age 5 and 6 began at age 7. Again, the older children when entering the study seemed to show more change. Interestingly enough, in the third year the construct our children showed most in their journals after design partner, was learner, followed closely by inventor. Almost all of the learners were the children that started at age 5, and almost all of the inventors were the children that started at age 7, suggesting perhaps that 7 may be a better age to begin this type of experience than 5. The construct found the least in the children's journals was critic, and this was for the most part similar for both age groups.

What we found most interesting was the rate of change shown in the children's journals over the three years. It was not actually until the third year that the majority of children reflected something other than learner in their journals. And in looking at where the children most clustered, interestingly enough it was either at learner or design partner, suggesting either children understood this partnership to be "real" or to be a classroom exercise. We believe that this may be due to a combination of factors, ranging from the actual research activities we undertook to the amount of time KidStory researchers who could be in the school. These factors will be further explored in the Discussion section that follows.

In summarizing our analysis of the journals, the figures that follow describe the changes in constructs in the children's journals.

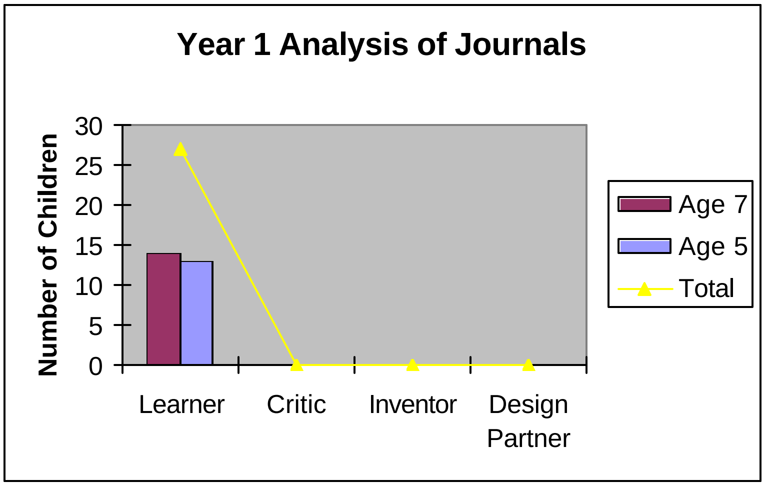

Figure 9: Children's Year 1 Constructs Displayed in Journals

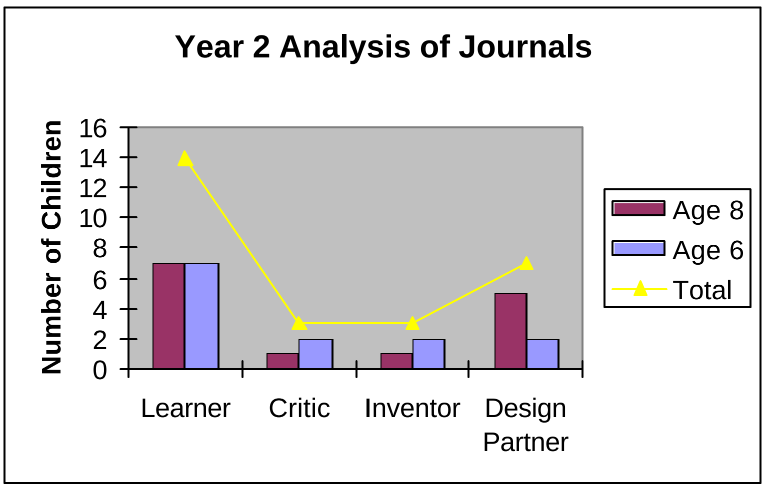

Figure 10: Children's Year 2 Constructs Displayed in Journals

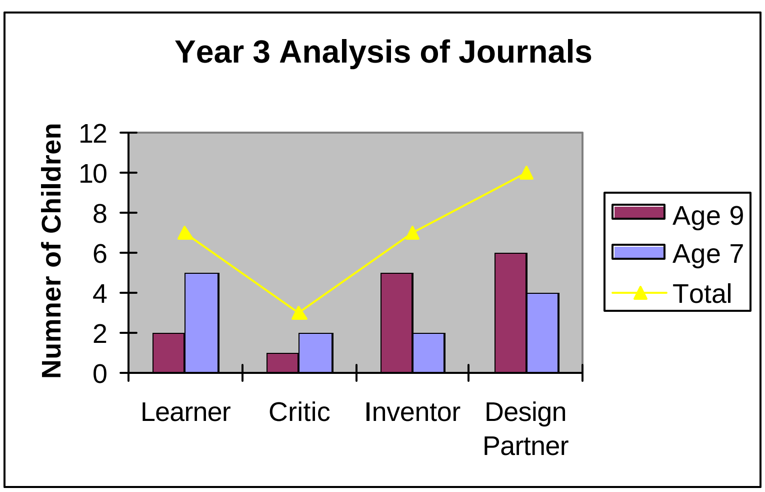

Figure 11: Children's Year 3 Constructs Displayed in Journals

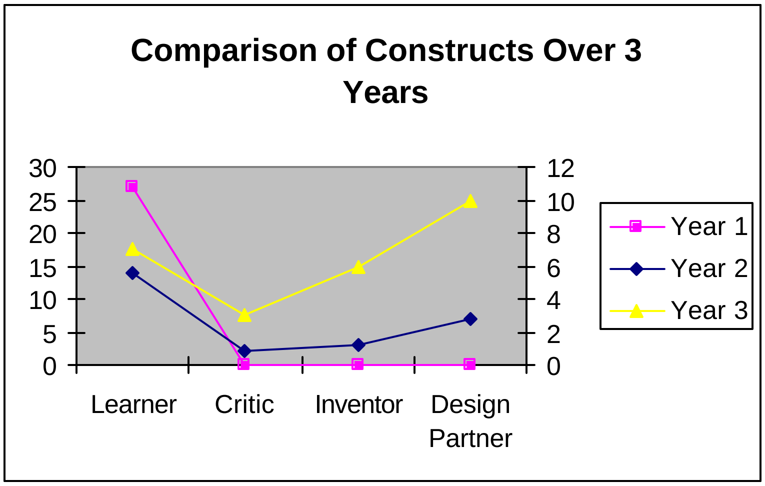

Figure 12: Comparison of Total Children Over 3 Years with Constructs

4.0 Discussion

In the sections that follow we will discuss the implications of what we have learned from our research experience with children as learners, critics, inventors, and design partners. Both the methods we used in the classrooms, as well as the outcomes we have seen in the journals will be discussed.

4.1 Lessons learned

4.1.1 Teaching/learning

Over the three years that we used journals in our research, we came to see this method as something not only helpful to chronicle the research activities, but as a method to help children develop and structure their thoughts. We have seen the joy that the children have taken in rereading what they have drawn and written. For example there was Yalda who wished she could show her journal to her grandmother who lived in Afghanistan. We have also seen how the use of journals helped the children to create meaning out of what we had done together. This was exemplified by Fatima who explained, "My journal is like a brain office." The journals have also been a help for us, the researchers, as an instrument for evaluation. We discovered sides of the children and their learning that we didn't see during the sessions in the classroom. There were many times that a whole classroom of children made it difficult to hear from each and every child in our technology design partnership. Some of our children were shyer than others, and with so many bilingual children, it may have been more difficult for some children to respond to research activities without time for reflection and at times translation. While these class sizes were not large by American standards, they were much larger than traditional research teams, therefore we learned the true value of the journals in helping us to capture more than we could just being present in the classroom.

In regards to the analysis of the children's journals, we have seen that children can learn from participating in the process of invention. They may discover more about the invention process, the technologies themselves, the use of those inventions for storytelling, and even more about their communication and collaboration skills. It was encouraging to see that children can move from learning about the process of invention to actually contributing to the invention experience. We were concerned that if all of our children displayed signs in the journals of moving at the same rate, then we had to assume that the journals were merely a mirror reflection of our research activities and not a window to a child's individual learning and change. That was not the case, we saw children clearly change at different times at different points, and some did not change at all.

What we did see was that this process of change needed time to happen. This may be due to the frequency and amount of time that could be devoted to work in the schools and the amount of children that were to be a part of the project with the number of adults. As a point of comparison, the first author of this paper and her colleagues at the University of Maryland have done similar research with children as partners in the invention process. What they have found is that meeting twice a week with only 8 children (7-11 years old), each week over the school year, and two weeks during the summer—the children still do not move from being learners to being design partners for approximately 6 months (Alborzi et al., 2000). On the other hand, with the resources of KidStory, researchers met once every other week with four times as many children, many of whom were younger and spoke Swedish as a second language. The challenges were much greater.

Based on this study's research results however, we now question whether working with children as young as five years old is useful for the children or the technology design partnership. It may be with greater time and more adult partners, this may be overcome, but further empirical study is needed to fully explore this issue.

4.1.2 Making new technologies

From this study, we also learned about the process of making new technologies. We learned that our design methods needed to be adapted for the number of children that were to participate in the invention process. Traditional classroom methods of teaching could not be used. We found that hands-on experiences where the children were a part of making something were the most successful (and perhaps more so for our bilingual students). We did find it critical that for the children to truly believe they were a part of something that was more than a classroom exercise, that we had to keep revising the technologies based on the children's ideas. The more the children saw the changes/inventions that they suggested in their journals/brainstorming sessions/technology use sessions, the more the children came to trust us that they were a critical part of making new technologies.

In regards to the actual technologies that have been made, much can be said of the technical merit of this work. Countless research papers, conference presentations, and successful European Union reviews confirm that the technical and educational research communities see the importance of what has been created and how it has been created (Alborzi et al., 2000; Benford et al., 2000; Fast & Kjellin, 2000; Taxen et al., 2001). We have also been encouraged by the use of many of our first year technologies. Today those technologies are being used on a day-to-day basis in Sweden, England, and the United States.

4.1.3 Limitations of the research

While we see the merit of this current research, we also see that there are limitations. We know that journals can only chronicle so much of our research efforts. While we have tried to add to the self-report of the children with adult researcher reflections and participant observation, our resources have been limited in what can be captured and analyzed in so large a project. We believe now that additional video archives could have helped in our reflection process. We also know that while 27 children is a great many to follow on a qualitative case study basis, it would be have been helpful to have been able to compare these children to those of our partners in England. This however was not possible since their methods differed from ours due to the structure and culture of the schools. In addition, the number of children in England that were ultimately involved in all three years of the project was only a handful, again due to the structures of the school.

Other research studies (Bruner, 1990; Heath, 1983; Wells, 1987) have shown that the sociocultural environment a child grows up in can also play a role in if the child feels comfortable being a partner with other children and adults. We believe that many of our children as recent immigrants to Sweden, had challenges in this area. Therefore the results of this study may be limited in how it can relate to other populations. Also related to this, we wonder if the journal results could have differed had the children been able to express themselves in their mother tongue.

4.1.4 Possibilities for the future

We would like to replicate our research methods with new groups of children both in Sweden and the United States. One such project has begun by the first author of this paper in Maryland, US with the support of a National Science Foundation Career grant. Children (ages 3-6) are participating in the development of the classroom of the future. Together children, teachers, and researchers are partnering to invent new technologies that can support young children in creative, playful, active learning experiences. We look forward to comparing our results in how children can change as learners, critics, inventors, and design partners. In addition, we have also begun a study to further develop these constructs using video archives of design teams with children. We believe that particularly the constructs of design partner and inventor could be better exemplified with the use of video.

In addition to replicating our methods, we hope to further evaluate the technologies that were created through the KidStory project. More empirical studies may help us to understand the value of our research methods in regards to technology development.

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