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Developing Software for Children: Experiences from Creating a 3D Drawing Application

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Abstract

The creation of good software for children poses a particular challenge to interface designers. This paper explores lessons learned during the design and development of a 3D drawing application for children with children. It focuses on the user-centered design approach especially towards children-designer experiences in conducting the evaluation process throughout different development stages with children of a broad range of ages. We argue that developers can optimize their software with children as design partner, especially in the evaluation process by seizing the children's abilities and directness in criticism. By enabling children to become partners—according to their capabilities—in the design and evaluation process, they can give relevant input not only to improve the product but also to contribute to best practice examples for children software.

1 Designing Software for Children

Children use computers especially for education and entertainment and the usage of computer technology has opened a variety of new applications for children on the market (Druin & Solomon 1996) including writing, drawing, reading most and notably computer games. Designers of these applications have long been concerned with the user expectation towards their product, with ease-of-use often been the primary design goal. For nearly three decades, the multi-disciplinary design approach has shaped our understanding of system design. It is always a challenging task to develop an application that combines software functions and the user's mental model. Even more, if the users are children, the challenge to design adequate, nontrivial applications for them becomes much harder. Unfortunately, only few software products were tested in cooperation with real users including nearly all existing software for children on the market today, except for games. Only recently, more and more researchers, educators and practitioners in the HCI community are moving forward in focusing on children as participants in the design process (Chiasson & Gutwin 2005; Donker & Reitsma

2004). Children's involvement in software design is increasingly on its way to become a common approach to obtain a high-quality product.

Recently, more and more researchers argue that children can be valuable design-, test-, and evaluation partners in an educational software project (Druin et. al. 1999; Kafai 1999). Surprisingly, most of the research concerned with children as serious partners, originated from visionary researchers with a very idealistic credo; i.e. people like Jean Piaget, Seymour Papert or Alan Kay giving direction to the field of 'Interaction Design for Children'. Throughout this study, we strongly argue for a participation of children in the design process, as we experienced that meaningful inputs and significant ideas from the children can be very beneficial to the interaction design and result in a better and more usable product for children. One main issue was to find the most appropriate way to integrate children in the development process (user centered design) and the evaluation in order to obtain verbalization and behavior data that really confirms the HCI-hypotheses (which can be quite difficult if the testers are not even able to read and write).

1.1 Interaction Design for Children

Interaction designers just started to develop design principles for children, and some believe that different principles should apply for children (Druin et. al. 1999; Druin 2005) than for adults. Obviously, this results from the capabilities of the specific age group (i.e. there is no sense in text feedback, if the users are not yet able to read). Most software products for children aim at education and entertainment, but lack a children-adequate interaction design. This even applies to games, as most game designers do not follow explicit design guidelines but intrinsic knowledge and rules of thumb about interaction design for applications targeted at children. Only recently, more and more researchers started to look upon user motivation, engagement, and task efficiency aspects. Surprisingly, as every user centered design approach should take care of the needs, wants, and limitations of the end users at each stage of the design process. This is even more important, if the abilities, skills and expectations, cannot simply be deduced from the assumptions of an adult interaction designer or software developer. In addition, designers of products for children must not only concentrate on the interface design, but also on features that will keep the children engaged in the usage of the product. These lessons can be learned from game designers that focus more and more upon a temporal interaction design to evoke an optimal flow experience. This can be done more effectively in a narrative context than in a software tool. Actually, most software companies do not apply the evaluating phase in their software development either due to lack of knowledge or due to budget or time restrictions (Jones et. al. 2003). Awkwardly, some of them just outsource the evaluation process to the market and let the end user evaluate the product. In many cases, most edutainment and education software developers of children's software do not involve their target group in any design and development phase at all.

1.2 Drawing as Children's Activity

From the earliest childhood, children appear to get considerable pleasure from watching shapes and colors appearing when drawing with a crayon on paper. According to Escobedo

& Bhargava (1991), children will progress five qualitative stages when beginning to draw with pencils and paper: random scribbles, controlled scribbles, basic forms, early pictorial, and later pictorial. This research indicates useful input for the design and development of any drawing software for children, as they will pass the same stages of development when learning to draw on computers. Thus, a digital drawing application should assist in producing the desired shapes and colors in order to quicken the creativity and expression of child art. Many digital drawing tools for children suggest different approaches for drawing, e.g., using keyboard, mouse, joystick, pen and tablet, eye tracking, speech recognition, and even fingers. For each particular input method, there are benefits and drawbacks in using it. Related research on using the mouse as input device for children are discussed by Hourcade et. al. (2004) and Inkpen (2001). When the children used the keyboard as an input device, it was difficult for them to handle, while natural language technologies of speech and eye recognition may be more suitable for disabled users. KidPad, an authoring tool for digital storytelling focuses on the use of several mice in order to facilitate creativity and collaboration (www.kidpad.org). But the use of non-standard interfaces always faces the danger of resulting in niche products as they are expensive, technically fragile or unavailable to larger audiences. A simple pen is still unbeaten in terms of intuitive and easy use, but a digital tablet simply is widely uncommon as input device. However, more and more children already know how to use the mouse, which makes the mouse the 'best second choice' as input device for children software, even for a drawing tool.

1.3 Making 3D Content Creation Accessible to Children

To some extent, drawing is a superior natural communication method because it offers a non-verbal way for children to express their thoughts and feelings. However, most drawing tools only offer 2D environments for drawing activities. Pen and pencil are replaced by the mouse and the resulting pictures are 2D images without exceptions. The third dimension was always reserved to professional 3D modeling or CAD tools. Our approach (cf. Fig. 1) was influenced by the Teddy project (Igarashi et. al. 1999), which introduced a new way of enabling non-professional users to create 3D freeform surfaces from 2D images. We extended the

Figure 1: The principle of extracting 3D shapes from a 2D drawing in our system prototype JIVE. The painting canvas still resembled those of conventional drawing applications and was not particularly suitable for children.

technique of extruding 3D shapes from a 2D drawing to create a 3D objects in a virtual world. A first prototype of a children-specific software that used this concept of drawing, scripting actions and interacting in 3D (Hintze & Masuch 2004) showed enormous potential.

2 Plopp–Developing a 3D Drawing Application with a Focus on Usability for Children

The core goal of Plopp was to create a completely new kind of drawing software for children supporting their creativity and artistic skills in 3D. Essential criteria were ease of use and interaction adequateness according to abilities and needs of children of the target age of five to ten years. The drawing tool provides multiple drawing functionalities. Objects, underground and background of a 3D scene are created in separate drawing windows. Drawing takes place on a 2D canvas. A desk's drawer metaphor is used to structure and simplify the interface layout and a palette analogy is used as resemblance to an actual drawing environment of an artist. Objects can be extruded to 3D with aid of an 'inflating' metaphor. Prepared drawings and outline drawings can also be used and modified. Saving and loading of elements like objects, background or underground, and also of complete scenes is specifically simplified for children. Children do not have to deal with file names or choose folders to store the drawings, as they deal with thumbnails within the application interface. Furthermore, Plopp provides several interaction functions like printing, sending e-cards and loading images up to a public online gallery. All functions are represented in an integrated interface, using icons that are grouped to functional areas. A flap metaphor is used to organize the application window, and to help children to focus on doing only one activity at one moment. The tool also provides a personalized acoustic and visual help support.

2.1 User Interface and Interaction

Inspired by manipulation handles of professional 3D modeling tools, a 3D manipulation widget was built to allow simplified 3D interaction like rotation, scaling and movement of

Figure 2: Interacting in 3D world with several handles (copy, redraw, delete, resize, rotate and move).

the objects in the 3D world (cf. Fig. 2). Furthermore, the object can be edited and copied. At the upper-right of the Plopp interfaces screen, there is the symbol of a half sun and a half moon indicating the lighting conditions of the 3D scene and the direction of the light source. Colors can be chosen either from an existing palette or from a simulation of color composition, which is unique in children software. The children can experience on mixing five colors with three primary colors—red, blue and yellow—and two monochromatic colors— black and white—to lighten or darken the other colors.

The intention was to provide the same experience for children they make when mixing colors in the real world and not to limit them in coloring by a fixed palette of discrete colors. The canvas used in Plopp resembles the canvas used in a real world environment with varying sized pencils and erasers, a paint bucket for filling bounded areas. Within the drawing canvas the mouse pointer behaves like a brush. The size of this brush can be chosen in the drawing window interface (cf. Fig. 3).

Figure 3: The Plopp 2D drawing interface shows a canvas and icons. A drawer metaphor lets the icons on the left slide open representing drawers for a collection of objects, skies, and grounds.

As part of the user-centered design process, we collected suggestions from the children during the development process. During the early stages of this process the main concerns of children were not questions about functionality but about sharing their pieces of art like "How can I show this picture to my parents and all my friends?" The children were also communicating with each other and showed what they did. This convinced us to support a common printing functionality with minimal options and a possibility for an image exchange using electronic postcards by mail (e-cards), and to create a platform for presenting pictures in a public online gallery. This not only enriches the program: Proudly displaying their masterpieces satisfies the children's needs for acceptance, communication and feedback. Beyond these functions we introduced the children to common web technology used by adults every day. Children can use these function, as far as they are presented in a proper and understandable interface metaphor. Like other users they should not be bothered with unnecessary technical details like filenames or switching applications to send an e-card or to load up a picture

to the gallery. Even if they knew some of the functions, not all of them knew what the Internet or an e-card is; but they understand this to be the best way to share their drawings with friends and family after a brief explanation. We were even taken with the open-mindedness of the children towards unknown technology. The target groups for Plopp were children at kindergarten and school, aged between five and ten years. At this age, the children's ability to read and write varies and cannot be taken for granted. For this reason, the mouse was chosen as solely input device and all text based interaction was abandoned. Instead, Plopp offers feedback in acoustic form. A personalized helper named Plipp offers help and advice using a set of prerecorded messages. Plipp can welcome and bid farewell to the children and guides and supports the children during the whole interaction process with Plopp. He speaks a simple, unambiguous language to be easily understandable for children with a level comparable to the children's linguistic abilities. Whenever a child does not know what to do next or does not understand an icon or function, he or she just has to click on the particular areas and Plipp will offer assistance and deeper information. Plopp also provides an extensive introductory tutorial guided by Plipp provided as an embedded, recallable animation.

2.2 A User Centered Development Process

The idea of easily creating 3D scenes was inspired by a simplified technique of shape extrusion in the JIVE prototype. For this new kind of drawing software for children, an appropriate interface and interaction design (including the essential functionality) was developed by professional designers and software developers from scratch, unbiased by WIMP standards. Two prototypes have been developed and the final version was evaluated in an informal user study. Afterwards, many improvements and bug fixes have been encoded in the final application. During this process, a number of children have been asked about their opinion on functions and design issues. Although this integration of the later users in the development process was rather informal, we constantly gathered essential information about the interface and the interaction design. Substantial design decisions for the user interface, the main concept and functions remained unchanged, but many details and interface elements (like the look of Plipp) were changed and optimized according to the feedback from the children. So, the software was gradually optimized, running through several of these user-feedback loops.

2.3 Evaluation Process

The evaluation took place during the alpha and beta phase of the software development process in a status in which the user interface and all major functionalities had been implemented. The primary goal of the user study was to verify and optimize the usability of the Plopp interface for children aged six to ten. Intuitive use, fun and creativity were intensively tested. Even though the children followed the narrative support of Plipp, the helping character, some children needed specific creative impulses and respective ideas for the painting. This was the only major direct intervention by the tester. The tests have been conducted in several nurseries and primary schools, mainly with children aged between five and ten years. But the research also included one four and one twelve year old child. All in all some 40 children participated in the development feedbacks and the final evaluations. The tests were run using either a classroom set of apple laptops or the available computer environment of the schools.

The goal of the evaluation was explained to each child. Afterwards, the children were instructed how to paint and the main features of Plopp were explained. In a second run, this was done by Plipp testing the effectiveness of the tutorial. The testing was conducted by one supervisor responsible for the evaluation and helping personal. The children were able to work and experiment with Plopp freely and at their own speed. They were observed regarding their attitudes and behaviors towards the use of the drawing tool. All interactions were logged by internal procedures in order to keep track of bugs and to recall system crashes or problems children encountered using Plopp. During the usage and afterward the children were questioned about what they liked and disliked and how usability could be improved.

The evaluation of this project was lead by the Games Group of the University of Magdeburg and was rather an informal than a formal evaluation. This was a highly disputed discussion, but Impara as company was mainly interested in raising the product's quality. In addition to that concerns about the children's privacies were raised by school authorities, so no statistically usable data was collected. Finally, only the children's interactions with the drawing tool were recorded in the background and qualitative data about the interaction was gathered. Several evaluation turns were accomplished, whereby some children were chosen to work with every single of the refined versions of Plopp in order to verify the advances. As a side effect, these student testers became very confident in using the tool and acted as helpers and advisors for other children. All in all, the children did not expose any problems in using the application even if they started with no computer literacy at all.

2.4 Observations

Some differences became obvious within the evaluation turns between nursery and primary schools, i.e. the different educational concepts of the overall organization of learning seems to have a strong influence on the children's way to approach a given task. As we tested in several institutions, this impression can be generalized. Within the kindergarten (which in Germany resembles more the pre-school settings of Anglo-American countries) the children freely participated in the experiment and approached the setting very naïve and unbiased. The children tried their best and painted simple and loose basic pictures. However, they needed some assistance on how to find the drawing tools and on how 3D world work. They needed iteratively organized tasks to familiarize with most of the features offered by Plopp, but did not care much about the representation of the 3D scene. The idea of separating 3D objects and background was very uncommon to them, but the interaction with these elements turned out to be nicely blended in the user interface. Thus, the interaction was very accessible and widely accepted by the children. For consistency and functionality reasons, for example, similar elements were arranged similar and some were re-arranged and re-grouped. These layout considerations had to be explained to the children in order to let them make use of the full functionality of Plopp. Assumptions can be derived that user interfaces for children are subject to other organizational and functional criteria than user interfaces for adults. Children would have organized it according to their preferences discarding functional groups (shapes, colors etc.), but got used to the layout fast.

Handling the mouse as input device for drawing was less problematic than expected. Many children already had prior experiences in using the computer, particularly the mouse. The

actual process of painting precisely with the mouse turned out to be generally difficult, since pen movements offer more degrees of freedom and superior manual experience. But the children—especially the younger ones—did not care about these drawbacks. In fact, they continued with drawing and kept on practicing. After a certain period of time, they mastered to draw with the mouse and became deeply engaged and motivated to try out new things. The smaller children hardly needed any creative impulse for painting, drew ideas from everyday life and included them into their pictures. Interestingly, there was a larger difference when conducting evaluation phases in the primary schools. Nine to ten year old children needed some specific task and had very different ideas about what to do with Plopp. For these users, examples of objects and painting templates became more important—far more important than for the younger ones, leaving us with thoughtful concerns about cliparts and creativity. Furthermore, the separation of figures and background caused difficulties, since the children were not familiar with this kind of drawing concepts and had no understanding of organizing components of a drawing with layers. For them, their previous knowledge of drawing played an important role. The more computer literate children asked for special functions and compared the program with the drawing software they already knew. They only understood the 3D function after drawing several times and/or sometimes they asked for help suggesting that their mental model of depicting the world already was biased by standard tools.

3 Discussion

Age and computer literacy of children played the most important role for handling the software and directly influenced the evaluating results. Below we list the findings that we derived from the evaluation with children using Plopp:

- Plopp is a very unique drawing tool as it allows the use of 3D objects in an image. Children were amazed by the capabilities of 3D, as they can inspect the 3D shape and explore benefits and possibilities of the extrusion function. They came up with many creative ideas what to draw and how to shape the objects. Thus, the children's creativity was not restricted to resize, reshape, duplicate and relocate the 3D object, but they could also use (and sometimes positively abuse) the functionality of the 3D shape extruder.
- Despite the inaccuracy of a mouse, children did not have problems in using it and draw their ideas free from any restrictions or boundaries. They cared not about the perfect drawing, but the freedom to express their ideas, and the process of drawing itself was the valuable experience. Only the smallest children had difficulties in handling the mouse, since its size was not at all ergonomic for them.
- Collaboration and sharing ideas among the children offered benefits and feedback for our software development and design. During the evaluation phase, the children wanted to share ideas with their friends on how to do certain drawings. This collaboration among children shows that they are not only learning to use the computer or the software, but they are also learning with their peers and share their knowledge.

- Due to different kinds of research settings (nursery schools, private and public schools), we found out that, in general, children from private schools exhibited more ideas, creativity and fantasy than others. This may be due to their specific environments where lots of drawings, paintings, mural and creative paintings surround the children. These children showed to be also very active and motivated in doing whatever they were told to do.
- The children did not understand the "drawer" metaphor in Plopp as good as expected. They were not able to relate the drawing canvas to the drawer they use in everyday life. A simple and brief explanation had to be given to them especially on how to use all the different drawers while painting.
- Younger children, unlike their older fellow testers, did not wanted to use the predefined shapes existing in Plopp, they preferred their own drawings, since they are nicer and more 'authentic'. While older children wanted to explore the whole functionality on their own, the younger ones wanted to get advice from the supervisor, whereas there are features provided to perform a specific function. Since the older ones were used to use different software before, they started to ask about what Plopp can provide.

4 Conclusion

In this paper we have presented an approach to understand the roles of children as evaluators for a 3D drawing tool. During the development process of Plopp we came to the insight that software for children should be necessarily designed and tested with children. Usability should not only be tested with children of the appropriate target group, but also with younger and older users. In extensive, yet informal user studies, we determined the usability and intuitive use of the interface, as well as the creativity flow during the testing process with children. Thus, it was our explicit goal to incorporate children into the development process.

Plopp enables children to produce 3D images without using complex 3D modeling techniques. The idea is focused on offering a tool for children to enable them to draw their own images that can be moved, rotated and scaled. Moreover, the objects are separated from their context, with Plopp as the background and underground. Thus, the children can create complete 3D worlds and expand them. A new 3D creation technique was embraced in order to make 3D accessible to children. The interaction design is based on a 2D drawing metaphor, keeping in mind that this is a technique that every child is accustomed to. Export and printing functions allow children to share their creative products with others. These functions have been simplified and limited but foresee the children's later digital life on the web to make them familiar with publishing and web technology.

Originally targeted at children aged six to ten, to our experience Plopp can be used by children of all ages starting at four years. For future research, we hope that further testing on computer supported drawing and creativity tools for children could be conducted in order to verify the more generalized statements of the above findings. However, the real challenge remains how to promote the new advancements in interaction design for children in order to create better products for our children.

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