Developmentally Situated Design (DSD): Making Theoretical Knowledge Accessible to Designers of Children's Technology

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ABSTRACT

There is a wealth of theoretical knowledge about the developmental abilities and skills of children. However, this knowledge is not readily accessible to designers of interactive products. In this paper, we present the requirements, design and evaluation of developmentally situated design (DSD) cards. DSD cards are a design tool that makes age specific information about children's developing cognitive, physical, social, and emotional abilities readily accessible for designers. Initial requirements were elicited through interviews with design practitioners and students. The cards were evaluated through a design-in-use study in which design students used the cards to address three different design problems. Our analysis of observational notes and post-design interviews revealed how the cards' characteristics enabled different kinds of uses including framing, orienting, inspiring, informing, integrating and constraining. We conclude with a discussion of possible refinements and an analysis of the strengths and weaknesses of our approach.

Author Keywords

Interaction design, design cards, design tools, design methods, child development, child-computer interaction.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; H.1.2 [User/Machine Systems]: Design.

General Terms: Design

INTRODUCTION

This paper describes the development of a card-based design tool to support designers in taking into account children's abilities and skills during various phases of the design

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process. It is assumed that designers need to apply knowledge about users in design approaches such as usercentred design [31] and participatory design [28]. They can do this in various ways. They can involve users as participants or they can use analytical methods or tools that contain knowledge about users. These two approaches are complementary. For example, in early design, users can be involved in a participatory design session and/or designers can apply design principles based on empirically generated knowledge, such as the principles for user interface design [29]. In the evaluation phase, a user interface design can be evaluated by having users interact with the interface using a think-aloud method [25] and/or it can be evaluated by having experts apply a usability inspection method such as cognitive walkthrough approach [20]. Many existing analytical tools and methods can be used fairly generically, but do not include specific knowledge about children.

Designers must understand and consider children's developmental abilities and limitations to ensure that products are appropriate for the intended age group [3, 6]. There are some design methods that facilitate the consideration children's developmental abilities in the design process. For example, the Nielsen Norman Group have developed as set of design guidelines for websites for children [16]. SEEM is a usability inspection method that can be used to evaluate computer games for children [4]. However, few of these approaches are based on knowledge about children's developmental stages, ages and abilities. Another issue is that existing methods are usually only usable in one phase of the design process (e.g. evaluation) rather than making information about child development available throughout the design process. An exception is Antle's childbased personas [1].

In this paper we begin by describing how we established the need to bring developmentally specific knowledge about children into the design process. We did this by interviewing design practitioners and design students about their approaches when designing with children. We translated their needs into specific requirements for a design tool. A design tool can take many forms from a software application that specifies type and placement of interface elements (e.g.

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ECLIPSE direct manipulation tool [12]) to non-computation materials that can inspire and inform design concepts (e.g. IDEO Methods Cards [19]). Based on prior work using cards in design (e.g. [17, 18, 21]), we decided to develop a card tool. We present our initial design of the DSD cards which are a set of 42 cards (14 developmental concepts x 3 age segments) that can be used in a variety of design activities. We evaluated the cards through a design-in-use study in which designers used the cards in three design cases which included concept development brainstorming and interface redesign for different children's age groups and classes of products. We present our analysis of how the characteristics of the cards enable certain kinds of uses which are ubiquitous in different design practices. We also present suggestions for the refined design of the DSD cards, and a discussion of strengths and weakness of our approach.

RELATED WORK

User Centred Design (UCD) involves iterative cycles of analysis, design and evaluation throughout the entire design process [31]. One key aspect of UCD is the recommendation to focus early on users and tasks [15]. Similarly, a principle for UCD practice for children is that there is no design that fits all, but rather design should be driven by knowledge of the target users [22]. The abilities and skills of children are different from adults' and change as children age and develop. Designers following a UCD approach for children in order to understand how to design for use that is "challenging but attainable for most children of a given age range, flexible enough to respond to inevitable individual variation, and consistent with children's ways of thinking and learning" [8, (p.161)].

While it is possible and desirable to design iteratively working with child participants (e.g. [11]) or informants (e.g. [26]), this does not guarantee that designs will be developmentally appropriate. Analytical methods that complement participatory approaches are needed.

Analytical design methods are based on theoretically and/or empirically derived knowledge. There is a wealth of theoretical information about child development. However, largely this information is dense, abstract and thus not accessible or usable for designers [1]. Sutcliff provides two requirements for theoretical knowledge to be applicable in design. First, the complexity of the theory has to be hidden from the designer. Second, knowledge has to be generalized so it can be used in a wide range of contexts [30]. In particular, knowledge about children's cognitive and physical skills and abilities, and emotional and social needs and abilities is important to ensure developmentally situated design [1]. What are needed are methods or tools which can be used to make theoretical knowledge about children's needs, skills and abilities accessible to designers.

There are various design methods and tools that facilitate incorporation of theoretical knowledge about users in the design process. For example, a Cognitive Walkthrough is a usability inspection method intended to introduce a theoretical model of how users learn through exploration of a problem (i.e. a new user interface) into a code walk through method [10]. The problem is that most of the most common analytical design methods (i.e. those taught in design and HCI schools) are not specific to children. A second problem is that despite many efforts to develop and market UCD tools, current studies show that the industry is still dominated by tools that do not support the activities and work styles of designers [7]. Rogers suggests that making theoretical knowledge easier to use requires a focus on the process of design [24]. What is needed is a child-specific design tool that makes theoretical knowledge accessible to designers *and* is developed to support how designers work in practice.

Developmentally Situated Design (DSD)

There are few child-specific methods or tools that can be used to facilitate developmentally situated design (DSD). However, there are several design frameworks that aim to incorporate theoretically derived information on child development into the design process. For example, the Child-Tangible-Interaction (CTI) Framework provides general concepts taken from developmental cognition which may be relevant for designers of tangible user interfaces for children [2]. CARSS (Context, Activities, Roles, Stakeholders, Skills), is a learner-centered design framework specifically for child learners [14]. Gelderblom presents ten lessons for designing for 5 to 8 years olds derived from theoretical and empirical research [13]. The benefit of these frameworks is that they provide theoretically derived concepts and considerations that may inform design. However, there are no methods or tools associated with them that can support designers to incorporate these ideas into the design process.

In the context of an industry design project, Antle describes and analyzes a method for creating and using child-personas in design [1]. The approach incorporates theoretical knowledge on the abilities and needs of children as well as and context specific design parameters into child-persona profiles. These profiles are then a tool that be used throughout the design process much like adult personas, as described by [9, 23]. However, the resultant child-personas contain information that is specific to a single design problem, and thus do not provide for reuse. We build on Antle's work in [1] with the development of the DSD card tool.

Cards as Design Tools

One approach that has been used to make conceptual knowledge from design frameworks both accessible and reusable in design is cards. Cards, like Post-it® Notes, are small which means that information must be presented simply and concisely. Their form enables a variety of uses, reuse (through their robust form), and supports a flexible hands-on approach to bringing conceptual information into design. Several design researchers have explored this

approach. For example, Hornecker presents cards and a card brainstorming exercise that transforms her conceptual tangible interaction framework themes into a tool for creative dialogue during design [18]. She describes a card game which can be used to provide the structure for using the cards in an early design phase. Lucero and Arrasvuori created *PLEX Cards* to communicate a framework about designing for playfulness [21]. They chose cards over other formats (e.g. poster, projection of PowerPoint slides, handouts) because they found that the affordances of cards brought the content *into* the design process better than the other formats. Halskov and Dalsgård present domain and technology cards and a method for using them called the Inspiration Card Workshop [17]. They provide a good overview of other research that has used cards as design tools.

Another approach is to use cards that contain information about user research methods. IDEO published a deck of 51 Methods Cards that represent diverse ways that designers can understand the people they are designing for [19].

We suggest that card sets are a *form* of design tool that can be used to make conceptual information accessible to designers and can be used to support designers how they work in practice.

INTERVIEWS WITH DESIGN PRACTITIONERS AND STUDENTS

To empirically validate the need for making theoretical information accessible and usable for designers and to gather input for the design of the DSD card tool we conducted interviews with design practitioners and design students both in person and using Skype.

Interview Method

We decided to interview both experienced design practitioners and design students to get a diverse perspective on possible use of theoretical knowledge in designing for children. The interview consisted of 20 open-ended questions asking about use of knowledge about children in their design practices, possibilities for improving future design practice by making knowledge more accessible and requirements for a possible card tool. The interviews took between 30 minutes and 1 hour. The participants were asked to focus on a single recent design project when answering their questions. The interviews were audio recorded and subsequently analyzed to search for evidence about the need for a DSD approach to design, as well as to gather insights and information related to requirements and potential uses for a DSD card tool. We looked for repeated themes as evidence for validation and to inform requirements, as well as using our own experience as designers to identify important and useful card requirements from the interview responses.

Participants

A total of six design practitioners and six design students participated in the study. The design practitioners had an average experience of 10 years of designing products for children. The design students were Master's and Ph.D. students who had an average experience of working on two design project for children. The participants worked in different countries, including Canada, Europe and the United States. They worked on a wide variety of projects, including websites, exhibit design, educational computer games, online games, intelligent toys, and communication products.

Results of Interviews

All interviewees felt that their design practice could be improved by a tool that made developmentally specific knowledge about children accessible in design. The interviews also provided information about a variety of design practices in which a DSD tool could be used, the ways that cards might be used in each practice, and characteristics of the cards that would contribute to the effectiveness and reuse.

Child-Design Practice Needs DSD

The participants described very diverse design practices in terms of the intended target users, the number of people working on a design team, the number and variety of stakeholders in a project, the technologies used in the project and the length of the projects. During these practices they applied different kinds of knowledge about children taken from a wide range of domains including: social psychology, learning theory and marketing theory. For example, one practitioner used the broad theory of Constructivism to loosely inform his design for an interactive museum exhibit. Another practitioner used the concept of the Zone of Proximal Development to inform specific design features in a web based learning activity. They also used more experiencebased information such as observations of children, visits to stores where products or toys for children were sold, and knowledge gleaned from other designers to inform all aspects of their designs.

Overall the interviewees felt that they would benefit from having easy access to information about the developmental stages of children during a design project. This would be complementary to some of the information they were already using. Several people mentioned that there was often a need for in-depth knowledge about a specific topic as well as easy accessible overviews of broad developmental topics. In some cases the interviewees felt that having a quick access to developmentally specific information might speed up the design process or that it might prevent them from making incorrect design decisions.

Less than half the interviewees had used explicit descriptions of the target user group (e.g. personas, user profiles) in their design practice. What they wanted was not a user profiling tool but a more flexible tool that would bring specific bits of information into their design process for a project. They also mentioned specific topics that they would be interested in including knowing about: play styles for different age groups, how children develop their sense of humor; and how children's interest in fantasy and more real-life topics develops over time.

Possible Uses of DSD Cards

Interviewees were largely positive about the idea of using DSD cards. They expressed many uses for such a set of cards designed to make theoretical knowledge about children accessible. For example, they gave the following possible ways the DSD cards could be used: in brainstorming to provide inspiration, to shift direction, or provide a starting point; as part of requirements elicitation; to inspire and inform early design concept development; as heuristics; as part of a design brief; to identity design constraints; as part of design guideline documents; to create personas; to understand tradeoffs through comparisons about how different designs meet different needs or skill levels; to inform specific design decisions; to redesign a user interface by providing information and focus on what to change; in design evaluation to identify the constructs and capabilities to evaluate; in a user study with children to support questioning about what they like and dislike about a design.

Based on Antle's previous work [1], we had initially thought that the cards might be used primarily to create personas that could be used in different projects. An important insight from talking to design practitioners and students was that the cards could be used much more widely than in the context of persona or user profile creation.

We also developed a more detailed understanding of how a card tool might be useful in relation to communicating with different stakeholders that participate in a design project. For example, the card tool could be used to bring a new team member up to speed about abilities of and assumptions about the user group. It could also be used to communicate design rationale for design decisions to clients in ways that were more credible than just talking. The cards could also be used to have (older) children discuss their abilities and interests.

Characteristics of the DSD Cards

The interviews also revealed suggestions about card characteristics that might make them usable in design practice. The cards should provide simple and up-to-date information. It would be useful if the source of the information was clear, so that more detailed information could be found easily and that the credibility of the information was evident. The cards should provide information about all aspects of child development including: cognitive, social, emotional, and physical development. Multiple team members should be able to easily and quickly use the cards. The tool used to create the cards should be open source, so that other people can contribute relevant knowledge.

Summary of Interviews

Design practitioners and design students do use knowledge about users in design. They use it both early in the design process to decide on global design decisions, and to make more detailed design decisions later. They do not always make explicit user profiles or descriptions of children for their projects. However, they would like easy access to information about developmental abilities of children and are interested in using a card tool that provides information about children's capabilities and interest. They indicated that such a card tool has the potential to be useful during the various design activities including: brainstorming, planning an evaluation session, presenting a design to a client or discussing a design with children users.

They suggested that such a tool would be complementary to the approaches they now use in design practice. Benefits of such a tool would be that it could be used as an inspiration source, it could speed up the design process, it could provide easy access to information during design activities with various stakeholders, and that it could prevent incorrect design decisions.

REQUIREMENTS FOR THE DSD CARD TOOL

Based on our literature review, our own experiences in designing and teaching about designing for children, and the results of the interviews, we developed with an initial set of requirements for the cards:

- 1. The cards should contain information about *cognitive*, *social*, *emotional* and *physical* development of children. These developmental categories should be easily distinguishable (e.g. by colour coding them).
- 2. Since most computational applications are designed to support and augment children's abilities, the cards should provide information about what children are *practicing* rather than what they can already do.
- 3. The information should be made accessible by writing it in layman's terms, focusing on the underlying concepts of development rather than describing complete developmental theories.
- 4. The information about abilities, skills and needs should also be made accessible through text and illustrations of children using both every day and computer-mediated activities and products.
- 5. The cards should be designed to be flexible enough that they can be used in variety of design activities and with different design methods [18].
- 6. The cards should be designed to facilitate collaboration [5].

THE DESIGN OF THE DSD CARDS

Based our goal to make theoretical knowledge about children accessible, usable and reusable in a wide variety of design practices and suggestions taken from the practitioner interviews, an initial design for a set of DSD cards was created (Figure 1). We started with sketches and iterated variations until we settled on a design that fit our goals. We worked with a graphic designer to formalize our design in a digital format and then created a sample set of 42 cards (available at www.antle.iat.sfu.ca/DSD).



Figure 1: Example card.

The main design rationale for the cards is described below. The four main developmental card types are colour coded to be easily recognizable: cognitive (blue), social (red), emotional (purple) and physical (green). The main category is followed by a sub-header describing the topic subcategory. The front of the card contains a textual description of the ability or skill children are practicing stated abstractly. For example, for the Cognitive category and has a topic subcategory Reasoning and Logic skills: Instructions for 7-9 age group, and the text is: "Practicing following a small sequence of instructions to achieve a task." Two pictures on the front show children engaged in this practice; one from everyday life, and one using an interactive product. The back of the card contains textual descriptions, presented as quotes from a girl and a boy, that concretely exemplify a way that a child can practice this skill in an everyday context. The descriptions include the activity, with whom they do it, what artifacts are involved, and where it takes place. For example, "She likes to make art projects with her two best friends on the dining room table." The bottom of the card shows the age range the information applies to.

The topics that are addressed by the initial card set are:

- **Cognitive**: reasoning and problem solving: instructions, reasoning and logic skills: problem solving, reading, information processing and working memory.
- **Emotional**: emotion expression, emotion regulation, emotion understanding.
- Social: self-esteem, perspective taking, friendships.
- **Physical**: locomotion, manipulation (gross), manipulation (fine) and stability.

These topics are not meant to be inclusive of all relevant topics, but rather to provide a sample of topics that we believe, based on our experience as designers, are important. In our experience, these topics may be relevant to specific types of children's interactive products or applications (e.g. gross motor skills for whole body interaction) or applicable to a wide variety of products (e.g. reasoning and problem solving: instructions) and thus would be appropriate to use to evaluate our card design.

Conceptual information for the cards was distilled from content in various textbooks on children's cognitive, social, emotional and physical development, from psychology and design journal articles on each specific topic, and from our own research publications. Examples were brainstormed and came largely from our in depth experience of working with children in both professional and non-professional life. At this stage content has not yet been validated through external review.

DESIGN-IN-USE STUDY

The purpose of the user study with design students was to evaluate the potential of a DSD tool based on our initial design of the card tool. Specifically, we wanted to examine in detail how designers would use the cards during different design activities. By examining how designers used the cards based on the cards' characteristics (content, presentation, form) we could evaluate our design and identify areas of improvement.

Study Design and Method

We combined an observational with an interview-based method. We conducted two similar studies at our universities (SFU in the Vancouver area of Canada and TU/e in Eindhoven, The Netherlands). We observed pairs or trios of design students doing three different design activities, one early concept development brainstorming task and two later stage redesigns of an existing solution. The design students first received an explanation about the DSD cards, and about the specifics of the first design case. They were told they could choose for themselves which cards to use. The cards were given to the students sorted by overall category and by age. They worked on the first design task for 30 minutes, followed by a short interview including questions about how they used the cards, what information was missing, and suggestions for changes. We then repeated this procedure for the second design case. In each location, we ended with a group discussion in which they were asked ten open questions. The questions probed how the cards might be useful in other design activities and asked for suggestions for changes. During the design tasks we observed how they used the cards, and noted down comments they made while using the cards. We recorded the interviews and took notes.

Participants

A total of nine design graduate students (Masters or Ph.D.) participated in the user study, four at SFU and five at TU/e. Six students were male, and three were female. Six students worked in pairs and three in a trio, and all groupings had worked together previously. The students had a background in either Industrial or Interaction Design, and had all worked on design projects for children before.

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Design Cases

We chose three design cases that we expected would have different design foci based on the design goal, kind of product, target age range and relevance of cognitive, social, emotional and physical developmental abilities of children. The first design case was an initial concept development of a tangible user interface to support 10 to 12 year old boys in sharing a sense of connectedness. The second case was a redesign of an older children's multi-touch tabletop game about sustainability to make it accessible for children of all ages. The third design case was a redesign of a simple adult online game to make it suitable for children aged 7 to 9 years.

One design case focused on a broad age group (case two), and two design cases focused on a narrow age group. The cases were chosen to examine the potential of the cards in early (concept development) and late stage (redesign) design activities. They also cover a broad range of product categories (tangible, tabletop, and web) so that the design students needed to consider different abilities. For example the first design case is focused on social-emotional needs. In each location, each group did the concept development design case, and one of the two redesign cases (based on the availability of the interface to be redesigned).

Results of the Design-in-Use Study

We analyzed our observational notes and interview responses for each design case. Each of us reviewed the data individually, and then compared our findings to look for commonalities and omissions. We identified behavioral patterns about how the designers used the cards to inform their design activities. For example, in design case two (redesign for broad ages) we both noticed that several times designers picked up two cards for the same concept and different age categories and compared children's abilities between age groups. We found that designers used the information about users both for developing a deeper understanding of the users (empathy) and for triggering new product ideas (inspiration). We found the following patterns of behavior related to how the designers used the cards based on the type of design activity and the characteristics of the cards. We group these by theme to demonstrate how the cards can be used to make developmental theory accessible in a variety of design activities and different projects.

Overall Uses and Feedback

The content provided by the DSD card tool was judged to be relevant for design. Participants mentioned that the topics for the four card categories needed to be extended, as we had explained in the introduction of the study. They made some suggestions for topics that they would be interested in, such as social play styles for different age segments.

Overall, the participants were satisfied with the manner in which the information was presented on the cards. They felt that the information on the front, which explains what abilities and skills children are practicing, was complementary to the information about specific examples of such activities in daily lives of children on the back of the cards.

The participants had many ideas about how to change the form of the cards. A more sturdy material for the cards would improve the cards' tangible properties. The card size and format was good for holding them, positioning them on the table and showing them to others. Some participants felt that a different shape, such as a hexagon shape would provide more opportunities to explore and show relationships between cards.

Orienting Team Members

Some students sorted through the cards to determine which cards were relevant for the design task in order to orient themselves to category topics and specific children's abilities as they selected a focus for the design problem. We observed that they initially did this individually but then used the cards to orient their team member(s). The cards' form supports this kind of collaboration by providing a tangible reference that designers use to come to a shared understanding of the nature of the design task (Figure 2). This is similar to the finding that cards were used as an orienting tool in brainstorming [18]. However, using the cards to orient each other was not limited to early concept development activities. It was observed in all the design cases.

Framing and Reframing the Problem Space

In all three design cases, we saw instances where the cards supported framing and reframing of the problem [27]. For example, at the beginning of the design case about redesigning the multi-touch tabletop game for younger children, one designer framed the problem narrowly. He sorted and grouped only the blue cognitive cards on the table and said "We need to change the cognitive aspects ... that's the focus." However, the second designer picked up the green physical cards (Figure 3) and said "You're thinking cognitive but it's a touch interface ... also manipulation. I'm going to grab this. There's manipulation gross and fine ...we need to think about this too." In this case, having the physical category of cards alerted the designers early on about the importance of considering not only age specific cognitive abilities but motor skills, reframing the problem more broadly.

Some groups systematically sorted through the stack of cards and selected which cards they thought were relevant to the design problem (framing) using the topics (i.e. simple concepts) but later came back to other topics by browsing discarded cards (reframing). For example in one case, the pair first divided the cards and each took two categories. They selected relevant topics, and discussed how they might be relevant (framing). Later on they looked back at the cards that were initially rejected to look for other topics that provided new angles (reframing). This type of activity was enabled because the cards can be sorted, categories were colour coded, and topics were simply and clearly stated near the top of the cards.



Figure 2: Orienting each other to key theoretical concepts or specific abilities through a common card reference.



Figure 3. Reframing the problem by considering physical cards (green) in addition to cognitive (blue).

Inspiration and Idea Generation

The text in the speech bubbles provides example activities that children enjoy and engage in. This can function as a source of inspiration. Since there are both girl and boy speech bubbles the cards were used for inspiration in the boys' only design case and more generally for all children in the other cases. The pictures were also good as a source of inspiration because the speech bubble text is very short and may be slightly ambiguous. Designers mentioned that keywords related to the pictures would enhance the interpretation of the pictures, although this might reduce their inspirational value by constraining interpretations.

Comparing Information

The cards can be used to compare abilities in different age categories and in this way inform design (Figure 4).

The front of the cards gives indication of abilities through text and an image. The back of the cards can be to determine what kind of actions and activities children are practicing. For example, in the multi-touch tabletop game redesign for younger children, the two designers were comparing several cognitive cards by looking at the photographs on the front and back for the same topics but different ages. One designer held up the reasoning and problem solving: instructions cards for the 5 - 6 and 7 - 9 year olds and said, "I'm trying to understand the difference between age groups – surely older can do what younger can do so target younger." The other designer then said, "But we need to think about, to make sure that the older kids won't get bored." The cards were used for comparing what children in different age segments could do to ensure that the design met children's needs based on concrete information.



Figure 4. Comparing the same topic for two age categories.

Expanding the Design Space

We saw various instances where participants combined cards from different categories to examine new possibilities (Figure 5). Often participants first go through all cards of one category to examine their relevance to the design problem. However, later in the sessions participants often explore combining cards from different categories (e.g. social and physical) to examine how this might inform design decisions.



Figure 5. Combining different categories.

Counter to our expectations that they might only consider the most obvious categories; almost all groups examined cards from all three or four categories for each design task. Combining different categories and topics supports designers to expand the design space by finding relationships between different cards. For example, the pair of students designing a tangible solution to support boys in feeling connected game up with a new design idea by combining the physical card of locomotion with an emotional card about expressing emotions.

Integrating with Other Design Materials

The physical nature of the cards; their small form and ease of handling supports designers to use them in an integrated fashion alongside other design materials. For example, they can be placed spatially on a sheet of paper where a designer is sketching out an interface design. We observed that designers used them in this way as a constant reminder about specific considerations represented by the card(s). The ability to place the cards virtually anywhere enabled the information on the cards to be referred to in the location where they are relevant. In contrast, consider a text book on child development that would have to be opened to specific pages for each design consideration. The cards provide a way of distributing and integrating information into the design process through their material form. They can be easily grouped, moved, flipped over etc. as needed to inform design.

Constraining the Design Solution

The cards can be used to help designers constrain the design solution by determining what children are not (yet) able to do. The text about skills children practice is concrete and provides opportunities for determining constraints. For example, in the multi-touch tabletop game redesign for younger children, one designer said, "*I'm trying to understand the parameters* … *No fine motor skill – not concerned with that. If they can use scissors and draw numbers they can use the user interface. They can't read – don't need that. Can follow simple step by step instructions. Need this.*" In this way he used went through a subset of the cards one by one to constrain what the design needed to address.

Post-Design Task Interviews

When asked how they might you use these cards in other design cases, the design students mentioned many of the uses for the cards that were the same as those that the design practitioners had mentioned including: ideation. communicating with clients, evaluation heuristics and a tool to work with older children. They also confirmed that the cards could be used to expand a design or constrain a solution, reframe by considering new factors, and provide concrete information as observed above. When asked how they would change the card design, they said it would be useful if you could quickly see the difference between the cards of different age segments, for example through colour coding or a tab-structure on the side of the cards. They felt the speech bubbles on the back were very useful to get a feel for the lives of children of a particular age, but would like to see more diverse examples of activities on the cards. For example, the physical cards mostly show examples related to physical games, but can be extended to other kinds of activities such as interacting with products.

When asked for suggestions for the tool redesign, the students expressed that they wanted aids to help explain how to use the cards (e.g. instruction sheet for each design case), an overview of the complete card set, and more information about relationships between cards. For example, how children's (social) ability of perspective taking is related to how their (cognitive) skills develop in reasoning and abstract thinking. They stated that would like to have references to other sources of information in case they wanted more indepth explanations. They were interested in being able to have a quick overview of how children develop over time (from one age segment to the next), for example in a table format. They suggested that there should be some way to customize the cards for a specific design problem. They suggested the idea of blank cards so they could add cards with information specifically relevant for their design project.

Summary of Design-in-Use Study

Our study provides evidence that the DSD card tool was usable in all three design exercises. We suggest that it has the potential to be useful in wide range of design contexts. The study limitations were the short time taken to explain the information structure of the cards, the limited time for each design case and that the design cases represented only two types of activities (early and late stage).

RE-DESIGN OF CARD TOOL

Based on the results of the design-in-use study we determined the following suggestions for changes to the DSD card tool and usage:

- Complement pictures that illustrate the activities that children practice with keywords covering important concepts related to the abilities children are practicing.
- Provide a quick-start guide that explains different ways in which the cards can be used in different design activities, such as brainstorming, presenting designs and evaluating designs.
- Provide an instruction leaflet to explain the underlying structure of the cards.
- Provide an overview document that lists all card categories and sub categories.
- Provide a document that provides an overview of how children develop over time for each of the card tool's sub categories.
- Provide a method to link between different cards when designers combine the information from these cards for a specific design solution.
- Add questions to the cards to help designers think about how to apply the information to the design process.
- Make the difference between the abstract activity that children practice (on the front of the card) and the concrete examples of the activities (on the back) more clear and consistent.
- Add a graphical element to enable designers to quickly find the cards related to a specific age segment.

• Make the examples in the speech bubbles more diverse to cover a wider range of activities of children.

We intend to use this list to redesign the DSD card tool. Some of these revisions may result in complementary materials in forms other than cards. Future design-in-use studies will guide the development and evaluation of the card-set (and possibly complementary materials).

DISCUSSION

Design and Development of the Cards

The iterative design process in which we have combined theoretical knowledge from literature resources with practicebased knowledge from design practitioners and design students has resulted in a hands-on card-based tool that provides designers with knowledge about abilities of children in different age segments. The design-in-use study provided more detailed design insights about the content, presentation and form of the cards. Both studies informed our thinking about possible uses of the card tool. The content of the tool was informed by information about specific cognitive, emotional, social and emotional topics that should be covered. The design of the presentation of the cards was validated. Designers liked the inclusion of text and pictures about activities that children practice when developing skills and abilities, and the two quotes by children that provide concrete examples of the contexts in which children practice these skills. The visual and textual information provides a good combination of knowledge and inspiration for designers. The card physical form facilitated handling, sharing, organizing, sorting, and other ways of using them that supported different ways of informing design during two design activities.

Using the Cards in Design Practice

Unlike several previous card tools that were designed specifically to provide inspiration early in the design process (e.g. [17, 18, 21]) the DSD tool can be used in different design activities (concept development, redesign) at both early and late stages in the design cycle as illustrated in our design-in-use study.

The DSD cards simplify and summarize what is sometimes complex conceptual information in order to make it accessible to designers. The danger of this approach is that concepts may be misunderstood or misapplied. The theory of perceptual affordances as put forward by J.J. Gibson and then adopted and adapted in HCI is a classic case of this over simplification. One way to rectify this is to find a way to link summary information on cards to more detailed explanations taken from primary sources. We leave this to future work.

Hornecker suggests that most theory inspired design frameworks are descriptive, explanatory and rhetorical and that they would be more productive if they were also generative [18]. By making the DSD cards more generic, we have not provided any specific mechanisms (e.g. questions) or methods (e.g. game structure) which would support generative use. There is a trade-off here between using tool presentation and form to support specific versus generic design activities. It may be difficult to do both. We also leave this to future work.

Many participants in both studies suggested that the cards should be customizable to the specifics of the design problem, or use illustrations that were familiar to the designers. While it is possible to provide editable cards and blank card templates, supporting this functionality would require a software application which is beyond the scope of this work.

One limitation of the card tool is that it outlines specific abilities of children rather than providing information on broad theories which may be used to inform design as suggested by several design practitioners in our initial interviews (e.g. constructivism in museums).

CONCLUSIONS AND FUTURE WORK

The DSD card tool provides designers with a flexible design tool that makes theoretical knowledge about child development accessible to designers *and* is developed to support how designers work in practice. As such it is a complementary to other materials and to methods that are based on involving children in the design process.

We intend to develop the cards further by extending the number of cards for each category, and by checking with a wider range of design projects whether some theoretical topics need to be added. We will further optimize the examples provided on the cards to provide a diverse view of what children's world looks like at different phases in their life. In the future, we may examine whether to extend the cards with a digital tool that provides an up-to-date link to literature resources for each card, and/or explore how other formats (e.g. poster, handouts) may complement cards. We have not examined how the DSD cards would be used by professional designers under real life constraints but we hope that the DSD cards will improve child-computer interaction research and design practice by enabling designers to incorporate accessible and reusable knowledge about child development into projects through the design process.

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REFERENCES

- 1. Antle, A.N. Child-based personas: Need, ability and experience. *Cognition, Technology & Work, Special Issue on Child Computer Interaction: Methodological Research 10* (2008), 155-166.
- 2. Antle, A.N. The CTI framework: Informing the design of tangible systems for children. In *Proc. TEI 2007*, ACM Press (2007), 195-202.

- 3. Baumgarten, M. Kids and the internet: a developmental summary. *Computers in Entertainment 1*, 1 (2003), 1-10.
- Bekker, M.M., Baauw, E. and Barendregt, W. A comparison of two analytical evaluation methods for educational computer games for young children. *Cognition, Technology and Work, 10*, 2 (2008), 129-140.
- 5. Brandt, E. and Messeter, J. Facilitating collaboration through design games. In *Proc. Conference on Participatory Design,* ACM Press (2004), 121-131.
- Bruckman, A., and Bandlow, A. HCI for kids. In Jacko, J., and Sears, A. (ed.) *Handbook of Human–Computer Interaction*, Lawrence Erlbaum, New Jersey, 2002, 428-440.
- 7. Campos, P. and Nunes, N. Towards useful and usable interaction design tools: CanonSketch, *Interacting with Computers 19*, 5-6 (2007), 597-613.
- Clements, D.H. Computers in early childhood mathematics. *Contemporary Issues in Early Childhood 3*, 2 (2002), 160-181.
- 9. Cooper, A. *The Inmates are Running the Asylum*. SAMA, Indianapolis, IN, USA, 1999.
- Dix, A., Finlay, J., Abowd, G.D. and Beale, R. *Human* Computer Interaction, Pearson Education Limited, Harlow, England, 2004.
- Druin, A. The role of children in the design of new technology. *Behaviour & Information Technology 21*, 1 (2002), 1-25.
- 12. England, D. A user interface design tool. *SIGCHI Bulletin* 19, 2, (1987).
- Gelderblom, H. and Kotzé, P. Ten design lessons from the literature on child development and children's use of technology. In *Proc. IDC 2009*, ACM Press (2009), 52-60.
- 14. Good, J. and Robertson, J., 16 (2006) 381-413. CARSS: A framework for learner-centered design with children. *International Journal of Artificial Intelligence in Education, 16* (2006), 381-413.
- 15. Gould, J.D. and Lewis, C. Designing for usability: Key principles and what designers think. *Communications of the ACM 28*, 3 (1985), 300 311
- 16. Group, Nielson Norman. Usability of Websites for Children: Design Guidelines for Targeting Users Aged 3– 12 Years (2010). Available at http://www.nngroup.com/reports/kids/.

- 17. Halskov, K. and Dalsgård, P. Inspiration card workshops. In *Proc. DIS 2006*, ACM Press (2006), 2-11.
- Hornecker, E. and Creative idea exploration within the structure of a guiding framework: the card brainstorming game. In *Proc. TEI 2010*, ACM Press (2010), 101-108.
- IDEO, IDEO Method Cards: 51 Ways to Inspire Design. William Stout Architectural Books, Palo Alto, CA, USA, 2003.
- Lewis, C.P., Wharton, C. and Rieman, J. Testing a walkthrough methodology for theory-based design of walk-up-and-use interfaces. In *Proc. CHI 1990*, ACM Press, (1990), 235–242.
- Lucero, A. and Arrasvuori, J. PLEX Cards: a source of inspiration when designing for playfulness. In Proc. *Fun* and Games 2010, ACM press (2010), 28-37.
- 22. Markopoulos, P. and Bekker, M.M. Interaction design and children. *Interacting with Computers*, *15*, 2 (2003), 141-149.
- 23. Pruitt, J. and Adlin, T. *The Persona Lifecycle: Keeping People in Mind Throughout Product Design*. Morgan Kaufmann, New York, NY, USA, 2006.
- 24. Rogers, Y. New theoretical approaches for humancomputer interaction. *Annual Review of Information, Science and Technology 38* (2004), 87-143.
- 25. Rubin, J., and Hudson, T. Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests. John Wiley & Sons, Inc, New York, NY, 1994
- 26. Scaife, M. and Rogers, Y. Kids as informants: telling us what we didn't know or confirming what we knew already? In Druin, A. (ed.) *The Design of Children's Technology*, Morgan Kaufman, NY, USA, 1998.
- 27. Schon, D.A. The Reflective Practioner. Perseus, 1983.
- Schuler, D., Namioka, A. Participatory Design: Principles and Practices. Erlbaum, Hillsdale, NJ, 1993.
- 29. Shneiderman, B. and Plaisant, C. *Designing the User Interface*. Addison-Wesley, NY, USA, 2010.
- Sutcliffe, A. On the effective use and reuse of HCI knowledge. ACM Transactions on Computer-Human Interaction 7, 2 (2000), 197-221.
- Vredenburg, C., Isensee, S. and Righi, C. User-Centered Design: An Integrated Approach. Prentice-Hall, Upper Saddle River, NJ, USA, 2002.