CREATING WEB PORTALS WITH CHILDREN AS DESIGNERS: BONDED DESIGN AND THE ZONE OF PROXIMAL DEVELOPMENT

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ABSTRACT. The article presents a new technology design methodology that the authors have termed "Bonded Design" and that was applied by two intergenerational teams comprising adults and grade-three elementary school students in one case, and adults and grade-six students in a second case. The objective of each team was to design a low-tech web portal prototype that elementary school students could use to find information on Canadian history to support class-based projects. The relationship between Bonded Design and Vygotsky's Zone of Proximal Development (ZPD) theory is explored, and the success of Bonded Design is explained in part by its use of the ZPD as a conceptual framework for the development of a community of designers.

CRÉATION DE PORTAILS WEB AVEC LES ENFANTS COMME CONCEPTEURS : CONCEPTION COLLABORATIVE ET LA ZONE DE DÉVELOPPEMENT PROXIMAL

RÉSUMÉ. L'article présente une nouvelle méthodologie de conception technologique que les auteurs ont appelée *Bonded Design* ou conception collaborative et qui a été appliquée par deux équipes intergénérationnelles composées d'adultes et d'élèves de troisième année du primaire dans un cas, et d'adultes et d'élèves de sixième année du primaire dans un deuxième cas. L'objectif de chaque équipe était de concevoir un prototype de portail Web d'une faible technicité que des élèves du primaire pourraient utiliser pour trouver de l'information sur l'histoire du Canada, afin de soutenir les projets en classe. La relation entre la conception collaborative et la théorie de Vygotsky sur la zone de développement proximal (ZDP) est explorée, et le succès de la conception collaborative s'explique en partie par son utilisation de la zone de développement proximal comme cadre conceptuel pour le développement d'une communautée de concepteurs.

INTRODUCTION

The Web is an open-ended information environment used by students as a place for exploration, discovery, and learning. In the context of project-based learning, the Web is an important resource, providing both the

means and content needed to complete school projects. Indeed, for many young people who have access to the Web, it is their preferred source for information resources.

Children, like adults, largely rely upon web portals (also called search engines) to identify and retrieve relevant web sites. A growing number of studies, however, are finding that primary and middle school students, although typically enthusiastic users of web portals, encounter problems in finding information to support their class projects and assignments (Schacter, Chung, & Dorr, 1998; Fidel et al., 1999; Hirsh, 1999; Large, Beheshti, & Moukdad, 1999; Wallace et al., 2000; Large & Beheshti, 2000; Bowler, Large & Rejskind, 2001). The barriers children face using web portals are many. The Web is a complex environment providing access to information from a variety of inconsistent and incompatible sources, the overwhelming majority of which are explicitly intended for adults. When searching, children typically encounter difficulties in selecting (and correctly spelling) appropriate keywords, formulating these keywords into search statements (which often requires a familiarity with Boolean logic), and revising a search strategy that fails to produce the desired results. When browsing menus or hyperlinks children often encounter navigational problems and become disoriented (Large, 2004).

The design of the web portal, its usability, can also contribute to the difficulties children face. Although there are many competing definitions, most experts would agree that usability describes the ability of the user to easily and intuitively understand, and then successfully navigate through, the components of an interface (Rubin, 1994; Rose, Shneiderman, & Plaisan, 1995; Head, 1997; Neilsen, 2000). Achieving usability is the task of the designer, not the user, and it therefore behooves the design community to explore methods to accomplish this. While we are in no way suggesting that the design of better technology will eliminate all the barriers that children face when searching the Web, we do suggest that children use web portals differently from adults and that it is essential therefore to design portals that are compatible with their developmental needs and personal interests in order to make information resources on the Web accessible to them. One way to achieve this may be to involve children in the design process. Although it is widely accepted that users generally should be consulted when designing information technologies, the extent and type of consultation when those users happen to be children is more controversial. Typically, children have been involved in testing new information technology products once an initial prototype design has been completed, so that their comments might be fed back into the final design concept. Rarely, however, have children played an active role in the design process, two exceptions being the work conducted by Allison Druin and her colleagues at the University of Maryland (see, for example, Druin, Stewart, Profit, et al., 1997; Druin, 1999, 2002; Druin,

Bederson, Weeks, et al., 2003; Guha et al., 2004) and our own research (Large et al., 2003, 2004, 2005, 2006a, 2006b).

This article presents a new design methodology related to but different from previous design methodologies employed with children. We have called this methodology Bonded Design because members of the design team, irrespective of their age, must rely on each other and "bond" their wisdom and knowledge in order to achieve a usable design (Large et al., 2006). The principles underlying Bonded Design were elaborated in the context of a research project that sought to develop two low-tech web portal prototypes using two intergenerational teams. (By "low-tech" we are referring to a visual but non-functioning prototype; one that illustrates design and layout, navigation, and the potential functionality of the portal.) The teams were comprised respectively of elementary students from grade three and grade six, each group supplemented with three adult researchers. The common task of each team was to design a low-tech portal prototype that would enable elementary school students to search for web-based information dealing with Canadian history. The team members – child and adult – worked side by side over several weeks exploring, negotiating, questioning, brainstorming, and sometimes heatedly debating as a community of designers.

Collaboration between adult and child, then, is the essence of Bonded Design. The methodology is therefore conceptually compatible with Vygotsky's Zone of Proximal Development, a notion that underpins sociocultural approaches to knowledge development (Vygotsky, 1978; Wood, 1998). This article will show, through concrete examples (dialogue, tools, and techniques) from the design sessions with the intergenerational teams, that Bonded Design offers a robust framework for eliciting responses from children on abstract information retrieval issues and for defining the role that children can play in the design process. The article begins with a description of the research context, followed by a review of the literature related to design and a brief description of the procedures that ensued during the design process. It then analyzes in closer detail the specific methods used, linking these methods to Vygotsky's Zone of Proximal Development.

THE RESEARCH CONTEXT

Two complementary objectives motivated this research: to identify the presentational and functional features in a web portal that would best support children when seeking information on the Web for school projects; and to explore the role that children themselves could play in this identification process. We were interested in elementary school children at the upper grade level (in Quebec, students in grade six) and at the intermediate level (grade three) who are already using the Web to find information but whose cognitive development is still in progress. In winter 2003, the authors embarked upon a research study that addressed three main research problems:

1. Can intergenerational design techniques be used to design web portals intended for use by elementary school students?

2. What design characteristics would be exhibited by such web portals?

3. How would elementary school students rate the portals as a means of finding information on the Web?

These three questions were to be explored within the context of designing two portals intended to enable elementary school students to find information for school projects specifically focused on Canadian history.

INTERFACE DESIGN METHODS

A number of design methods have been adopted and/or adapted and applied to children as users of information technologies in order to provide professional designers with input from their targeted user communities (Nesset & Large, 2004). They are, on a scale extending from the lowest level of user involvement to the highest, User-Centered Design, Contextual Design, Learner-Centered Design, Participatory Design, Informant Design, and Cooperative Inquiry (Carmel, Whitaker, & George, 1993; Scaife, Rogers, Aldrich, & Davies, 1997; Beyer & Holtzblatt, 1999; Druin, 1999; Scaife & Rogers, 1999).

The first and most conventional form of design that includes users in the process is termed User-Centered Design. In traditional User-Centered Design, the users are not introduced to the design process until the technology has already been developed and released onto the market. The main purpose is to identify and assess the end-users' goals and to ensure that the design has addressed them (Head, 1999). In this meaning of the term, User-Centered Design, technology users are employed only in the role of testers or evaluators (Scaiffe & Rogers, 1999) and the focus is on the impact of the technology on users (Druin, 2002), enabling the development of future versions of the existing technology or the design of completely new technologies. The major drawback of this approach to design is that because the user is only involved after the technology has been designed, s/he has little or no control over the process. Some authors, however, employ the term User-Centered Design in a fuller sense to mean direct contact between users and designers throughout the design process (Rubin, 1994).

Contextual Design was first articulated in response to the work-place needs of adults (Beyer & Holtzblatt, 1999). Contextual Design calls for researchers to collect data in the users' own environment by observing them performing typical activities. In the final stages, low-tech prototype mock-ups of the system are developed and tested with users. Although Contextual Design does not involve the final users of the product in all aspects of the design process, their opinions and suggestions are key pieces to be considered by the designers.

The use of low-tech paper prototypes, pictorial diagramming, and concrete techniques lends itself to work with children. In addition, Contextual Design does provide a framework for users' opinions and suggestions to be heard and considered by the designers. Contextual Design's emphasis on a team approach and concrete methods of pictorial flowchart data analysis make it applicable and appropriate in a child-centered context. From Contextual Design we borrowed three key elements: a perspective that views the designer and customer as one team, the technique of prototyping the product, and the use of visual data, such as pictures, for eliciting responses.

In Learner-Centered Design, it is assumed that everyone is a learner, whether a professional or a student (Soloway, Guzdial, & Hay, 1994). The focus of this design methodology is to ensure that the design is adapted to the interests, knowledge, and styles of the learners who will use it. Designers who follow this methodology ask: how will the learner learn by using it; how will it motivate a learner; how can it support different user approaches; and how will it accommodate learners as they change? Whereas in User-Centered Design the emphasis is on tasks (what does it need to do?), tools (what tools are provided to handle these tasks?), and interfaces (what is the interface to these tools?), the issues at the heart of Learner-Centered Design are understanding (how will the learner learn the practice?), motivation (how can software motivate a learner?), diversity (every learner is different – what can be developed that supports this?), and growth (the learner changes but the technology does not) (Soloway, Guzdial, & Hay, 1994). To address these learning issues, Soloway, Guzdial, and Hay (1994) recommend using a "scaffolding technique" to support learners while they are learning a new task. Kafai (2003) has adapted Soloway's approach for use with children by making them the actual software designers. Her research showed that young student designers are similar to professional designers in their concern for their users. They were conscious of, and tried to address such issues as, content and user motivation, but they did not always fully grasp how to address their users' other needs. Kafai is convinced, however, that children have the ability to become more than just informants in the design; rather, that they can become design process participants.

Participatory Design is based on the premise that users are the best qualified to determine how to improve their work and work life (Carmel, Whitaker, & George, 1993). Compromise rather than consensus is the goal. Contributions from the user of the product go beyond simply approval or supplying background data, moving the user to a position of "peer-designer, design owner, expertise contributor, and self-advocate" (Fleming, as quoted in Bilal, 2002). According to Carmel, Whitaker, and George (1993), there are two governing themes for the implementation of Participatory Design principles: in mutual reciprocal learning, users and designers teach each other about work practices and technical possibilities through joint experiences;

in "design by doing" interactive experimentation, modeling, and testing, hands-on designing and learning by doing are employed. It is a creative process using low-tech tools such as blackboards, index cards, and drawings to generate prototypes. A technique our research drew from Participatory Design is prototyping the product – building an early, low-tech version before implementing the final product.

Informant Design, developed by Scaife and his colleagues (1997), was introduced to address some of the perceived problems with user-centered and participatory design techniques when working with children. They considered that in User-Centered Design, where users are involved only as evaluators or testers at the end of the design process, it is up to the designers to translate and interpret the users' reactions and this can be an inaccurate practice. Their problem with Participatory Design is in its promotion of equality for all team members; they thought this approach to be effective for a team comprised of adult users who can view each other as peers, but infeasible when dealing with children. They do not believe that children have the time, knowledge, or expertise to fully participate in the collaborative Participatory Design model. Informant Design attempts to maximize the input of the participants at various stages of the design process. They advocate the use of a diversity of informants (e.g., teachers and children) to maximize the variety of suggestions. The designer tries to elicit suggestions from the children and then lets them know if it is possible to incorporate them into the working design. Scaife and his colleagues consider Informant Design to be the best method for the design of interactive software for non-typical users or those who cannot be equal partners (e.g., children). Its basic assumption is that, in the design process, children are most helpful at suggesting ideas for motivational and fun aspects of educational software.

Developed by Druin (1999) and her colleagues at the University of Maryland, Cooperative Inquiry is a combination of techniques from different design methodologies that have proven useful when working with children. It involves a multidisciplinary partnership with children, field research, and iterative low-tech and high-tech prototyping, and treats children as full design partners – equals to the professional adult designers on the team. Professional designers and users (children) of the technology are partnered in intergenerational design teams with the understanding that full participation of users requires training and active cooperation. Unlike Contextual Inquiry, with its minimal interaction between researcher and user, Cooperative Inquiry involves more than observation. Low-tech prototypes are developed by the entire intergenerational team in order to support the brainstorming and idea generation stage of the design process. Low-tech prototyping (e.g., paper-based prototypes), because of the nature of the activity and the materials used, also provides an equal footing for children and adults (Druin et al., 1999).

INSTRUCTIONAL DESIGN METHODS

Several design methods such as Rapid Prototyping and User-Design have emerged from the field of instructional design. While not explicitly related to the design of information products for children, they are worth noting. In Rapid Prototyping (RP), development and formative evaluation are undertaken concurrently and result in a series of prototypes (Tripp & Bichelmeyer, 1990; Stokes, Jones, & Richey, 2000). The degree of user involvement can vary, depending on the particular model of RP in use. Users typically participate in formative evaluation of the prototypes, but do not initiate the project nor contribute to the first design. However, some models of RP draw the user in at the earliest phases of the design process, even before a prototype has been built, in order to identify the intended audience and establish the goals and objectives of the project (Stokes, Jones, & Richey, 2000).

User-design, also from the field of instructional design, can be nested between Informant Design and Cooperative Inquiry (Carr, 1997; Carr-Chellman, Cuyar, & Breman, 1998). User-design engages users in the design process itself, with designers and users working together in a team. This approach redistributes power relationships between experts and novices so that, "control percolates from the ground up" (Carr-Chellman, Cuyar & Breman, p. 98). The shift in the user's role from advisor to creator distinguishes this approach from the more traditional User-Centered Design. Complete equality, however, is not a prerequisite for user-design; the purpose and goals of design projects are initiated from top down, and users who participate in the design process must still "work within the existing system" (p. 98).

RESEARCH METHOD

Participants and procedure

The research reported here was conducted in a public elementary school that is part of an English school board located in a middle class suburb of Montreal. As Montreal is located in Quebec, officially a French-speaking province, English schools in the public system typically follow a French immersion program. In this particular school, starting at grade three, half of the school day is spent in French and the other half in English.

Two gender-balanced, intergenerational design teams were established, randomly selected from a pool of volunteers. The grade-six team comprised eight student volunteers aged 11 or 12, and the grade-three team had six student volunteers aged eight or nine years. In each case the same three adult researchers were also team members – two females and one male

The design teams met in the school's art room, which was equipped with high-speed Internet access and where the sessions would be undisturbed. The grade-six team met for 13 sessions and the grade-three team for nine

sessions. These design sessions were held twice per week unless disrupted by holidays or school trips; competing lunchtime activities as well as the adults' schedules made more frequent meetings difficult, and less frequent meetings risked losing momentum, especially for the younger team.

The content of the grade-six sessions was based on criteria adapted from an information architecture matrix constructed by Large, Beheshti, and Cole (2002) for use in designing children's web portals. These criteria formed a "topic timetable" for the sessions. A timetable was important if a portal design was to be completed within the number of sessions planned. At the same time, when working with children it is essential to maintain flexibility. In the case of the grade-three sessions, it was more difficult to divide the sessions thematically; in practice any one session dealt with a variety of topics (for example, Session 2 covered elements of retrieval, help, email and chat). A typical session for both teams involved some/all of the following: a quick résumé of the previous session (while the children ate their packed lunches), team discussion of portal features, brainstorming about portal design, viewing existing portals on the Web, individual drawing of portals, and consensus building. In the case of the grade-three team, sessions typically ended with a physical game. All the sessions were audio taped, and notes were also taken by one of the research assistants. All the drawings were copied for later analysis.

The concrete results of the implementation of these design sessions were two low-tech web portal prototypes (described in Large et al., 2004); one by the grade-six team (see Figure 1) and the second by the grade-three team (see Figure 2). The low-tech prototypes were subsequently transformed into working portals and evaluated by students in the context of a school project. (See Large et al., 2005, for the preliminary evaluations of the portals.)

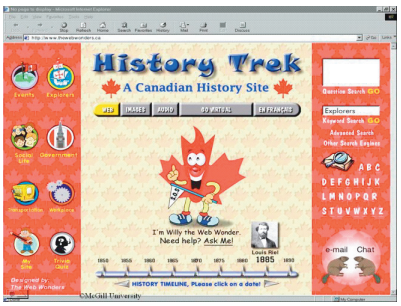

FIGURE 1.
Grade-six low-tech web portal prototype

FIGURE 2
Grade-three low-tech web portal prototype

BONDED DESIGN AND THE ZONE OF PROXIMAL DEVELOPMENT

Designers of information systems are almost universally adults who have expertise in information technology but whose childhoods are, regretfully perhaps, behind them and very difficult to recall with accuracy or authenticity. Children's motivations, perceptions, and ways of organizing and retrieving information remain hidden to designers within a black box called "childhood." One way for adult designers to open this box is to work side by side with children, in an environment that exposes children's perspectives. Bonded Design openly acknowledges, indeed encourages, an interdependent and collaborative relationship between adults and children in an intergenerational design team.

One way to understand the Bonded Design process is to look at it through the lens of Vygotsky's Zone of Proximal Development, a theoretical construct used to explain learning and development. The Zone of Proximal Development is the "distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). It is a dynamic developmental state. At the lower limit of the zone are the tasks that children can accomplish independently, while at the upper limit is the space where more complex tasks can be realized by children only through interactions with more knowledgeable others. The mental development of children, according to Vygotsky, should not be assessed by what they can do independently – their actual developmental level – but rather by what they can do with the assistance of others, which may be more indicative of their mental development than what they can do alone. The actual developmental level indicates only the beginning, "the 'buds' or 'flowers' of development rather than the 'fruits' of development" (1978, p. 86). These "fruits" can mature within the Zone of Proximal Development if given the support of more competent others.

Communication and social interaction are key features of the Zone of Proximal Development. Mediation between more knowledgeable others and the child is the critical mechanism of learning and development. How does mediation occur? Through dialogue and specific tools and techniques that are framed within collaborative activities. Knowledge-building in the Zone of Proximal Development is co-operatively achieved through the supportive framework, or scaffolding, provided by the mediation between expert and novice. Scaffolding can be adjusted and modified by the expert participant according to the novice's needs. Vygotsky did not believe that children come to know about the world by way of independent rediscovery of the knowledge that is already known by the rest of society – rather, knowledge is passed on by adults or more knowledgeable peers in the form of verbal definitions, delivered through the discourse between the expert and novice

(Karpov & Haywood, 1998). Interestingly, expertise and guidance may not always come from an adult. According to Vygotsky, child development occurs most rapidly when the child collaborates with others within his or her Zone of Proximal Development.

The Zone of Proximal Development and its associated concepts of mediation, collaboration, and scaffolding have been explored principally in the context of primary and middle school classrooms. Most notable is the work of Ann Brown, Annemarie Palincsar, and Joseph Campione, three early adopters of the theory of the ZPD (Brown & French, 1979; Brown & Palincsar, 1987; Brown & Campione, 1990; Brown, Metz, & Campione, 1996). One goal of their research was to investigate how to design socially supportive climates for learning. Calling the classroom a community of learners, Brown and Palinscar explored learning environments that would enable group participation and dialogic interaction (1996). Central to this environmental structure is a belief in the power of shared discourse, distributed expertise, and guided discovery. While some knowledge should be common to all, individuals within the community can have specializations, provided their expertise is distributed to others. Over time their individual expertise becomes common knowledge shared by the community.

Web portal design and the ZPD: A community of designers

When Brown and Palinscar (1987) applied the theory of the Zone of Proximal Development to their design of a classroom environment, their concept of a community of learners emerged. This can become a powerful notion to work with in the context of technology design and children. An intergenerational team consisting of adults with special knowledge about technology design and children with special knowledge of what it means to be a child can become such a community. Indeed, in the context of design, we might more properly call it a community of designers.

Our intergenerational design team was indeed a community. We began with a common goal – designing a low-level web portal prototype – that united the team; and expertise was shared and consensus built as we explored, negotiated, questioned, brainstormed, and debated. We met regularly during the children's lunch period, an unstructured time of day for most students. Interaction was not guided by strict decorum (although the students' safety and security were maintained at all times) and conversation was free and casual, with the students addressing the adults by their first names. The students looked forward to their meetings with the design team. Indeed, in final interviews, several expressed the wish that the project had run for a longer duration.

When we look at the design process through the lens of the Zone of Proximal Development we might rightly ask, what actually happened when our com-

munity of designers worked together? What was it that helped the youngest members expand their capabilities and discuss information retrieval and web portal design in ways that may have been foreign to their earlier thinking? For the adult team members, what was it that opened a window into a child's perspective? How did the team come together to achieve their objective – the design of a web portal for children? To understand how our community of designers worked together, this paper focuses on two aspects of the interaction between members: 1) dialogue and 2) the tools and techniques used to launch discussion.

Dialogue

Dialogue lies at the heart of the Zone of Proximal Development, typically framed within collaborative activities. Dialogue in an intergenerational team can potentially flow in several directions: from adult to child, child to child, and child to adult, although in practice it is difficult to know when one form of mediation begins and another ends. In our experience, mediation within the grade-six group was more democratically distributed than with the grade-three design team, due to the younger children's limited experiences using web portals and difficulties reaching consensus.

As mentioned earlier, Vygotsky did not believe that children come to know about the world exclusively through open-ended discovery. Knowledge transfer in the Zone of Proximal Development occurs primarily due to the verbal discourse between the more knowledgeable and less knowledgeable partners. Looked at through the framework of the intergenerational teams in our design study, this notion of knowledge transfer makes sense. The adults in our design team at times offered simple explanations of why portals worked the way they worked, rather than sitting back and waiting for the children to discover the reasons themselves. Often the explanations elicited responses from the children, allowing the adults to gain insight into children's thinking about web portals. For example, during an exploration of existing portals by the grade-six design team, the advanced search at Google was discussed. An adult member asked if anyone had ever tried it. None had, nor did they have any idea what it was for. A brief explanation followed, wherein it was pointed out by an adult that while advanced search was more precise, it also demanded more thinking from the user. Would other kids ever use it? The answer from the younger members of the team served to open a window on the children's thinking – it was a categorical no - it was too difficult! Clearly, fast and simple is the rule.

In another example of how adult-led explanation was used to generate new ideas and guide decisions about portal design, a grade-six boy suggested we use sound to catch the attention of portal users (music being a high priority for the children in the design teams). An adult member then pointed out that there could be "trade-offs" to having entertainment features on a portal

– sound and graphics can become annoying after visiting the portal a few times. The children had never considered this conflict before. Discussion followed and a possible solution was found – offer a choice of music so that users don't get bored. Understanding "trade-offs" might have played a role later on when, in session 9, the design team decided not to include sound as one of the components of their portal.

Often guidance from the adults was framed within a question which opened an area for discussion. During the grade-six session on e-mail and chat, questions were asked by the adult team members about how e-mail and chat might work on a portal intended to find information for school projects. Should we have both? Yes. What would be the difference between e-mail and chat on this portal? Chat would be for friends and e-mail for asking "experts" questions. What about having a teacher moderate the discussion in a chat room? An emphatic "no!" The children's responses illustrated a clear distinction between the socializing and learning functions of a school portal. In the final grade-six prototype, both e-mail and chat are included, but each has its own link (see Figure 1).

Working with the grade-three design team required a higher level of adult intervention in order to guide the conversation toward topics related to web portal design. Most of the children had never considered "finding information" as a distinct task and therefore had not considered what a web portal does, even though all had used the Internet. As a starting point, we began by looking at commonly used "adult" web portals such as Google and MSN, as well as several web portals such as Yahooligans!, KidsClick, and Lycoszone, designed by adults but for children. While doing so, we asked the children what they thought about specific functions of the portal. Answers reflected a growing awareness of web portal functionality. Asked what she thought of "Help" (user assistance), one child said she had never used it because she couldn't find it, but added that kids definitely need it. What should "Help" do? There was universal agreement that it should help you find information, teach you to use the Internet and, of course, do your homework. Two sessions later, the children seemed to have come to a more refined definition of "Help." Looking at a composite drawing of the web portal prototype, a drawing that incorporated ideas from all the junior members of the design team, the grade-three students were asked again what "Help" does. The reply this time emphasized searching the Web.

Difficulty in spelling was a theme that emerged early on in our questioning of grade-three students about web portals (and the working high-tech version of both portals includes spell checking). When asked what she thought of the alphabetic search on KidsClick, one child commented that it was "cool" and would be helpful "if you don't know spelling," although another child said kids also need to search by keyword even if they have

problems spelling, showing an awareness that there may be several ways to tackle an information problem. Interestingly, following this discussion, the alphabetical search showed up in four out of five drawings – the sixth child was missing that day – (see Figure 3 for an example of a drawing) and, by consensus, in the final low-tech prototype (see Figure 2).

FIGURE 3.
Drawing of a portal by grade-three student, showing "ways to find information," such as keyword search and alphabetical search

Vygotsky believed that development occurs most rapidly when children collaborate with others within their Zone of Proximal Development. Perhaps this is due to their ability to speak the same language or share the same conceptualization of a problem. Child-to-child or peer-to-peer mediation did occur in our design teams during group discussions. We also used specific techniques designed to elicit communication between children. For example, the grade-six children initiated discussion with their peers after the first design session by using a brief survey that they took to the school yard during recess (described below). Another method for encouraging child-to-child dialogue was the use of demonstrations. In both the grade-six and grade-three teams, demonstrations of existing portals were used to launch discussion about likes and dislikes. With one child at the control handling the mouse and keyboard, the group gathered around a computer screen to view (and critique) several existing web portals. The children were in charge of this exercise, deciding what to search and how. One grade-six boy took us on a guided tour of the International Children's Digital Library (http://www.icdlbooks.org) (which the children thought was too young for them due to the pictures). Another explored an experimental portal that uses a concept mapping approach through PubMed (http://www.pubmedcentral.nih.gov) (this they found "too old" because of the complexity of the mapping).

Tools and techniques

Specific strategies were used as a way to launch discussion and provide opportunities to work collaboratively toward one purpose. The collection of tools and techniques included: drawing, demonstrations, surveying fellow students, setting an agenda, and seating arrangements.

Drawing

Drawing is the premier method of eliciting discussion about design when working with children in an intergenerational team. Drawing serves many purposes when working in the Zone of Proximal Development. In the case of our design teams, it provided an invisible platform for group discussion. Drawing pictures of the ideal portal triggered much commentary around the table about portals, the children sharing knowledge and expressing new ideas quite unknowingly as they focused on their drawings. At times, drawing permitted discourse to continue simply by providing a diversion for students who had lost interest in the discussion. Rather than interrupt the conversation, they simply turned to their drawings for amusement.

In both the grade-six and grade-three teams, we used a "show and tell" approach upon completion of drawings, with each team member explaining his or her picture to the rest of the group. This "show and tell" procedure provided an excellent forum for sharing new ideas. Ideas from the adult "experts" in portal construction also found their way into the team's group work. For example, early in the grade-six design process, one of the adult members had included in his drawing a scrolling timeline as a way of finding information about events on particular dates in Canadian history. The first drawings from the children showed that they had not considered this retrieval option on their own and, as can be seen in the final version of the portal, the team did eventually adopt the timeline as one of the components of the web portal, providing an example of knowledge-building through collaboration (see Figure 1).

Verbal expression may be more difficult for the youngest designers, and other outlets for expression, such as drawing, may be necessary in order to share thinking within the group. Expressing metaphor is particularly tricky for young children. In the case of the grade-three design team, one child visualized the portal as her own computer at home, a place where she does her homework. She expressed this in her drawing (seen Figure 4), and the metaphor was eventually adopted by the others in the group. The final low-tech web portal prototype is indeed a computer placed on a child's desk, surrounded by some of the design team's favourite things (see Figure 2).

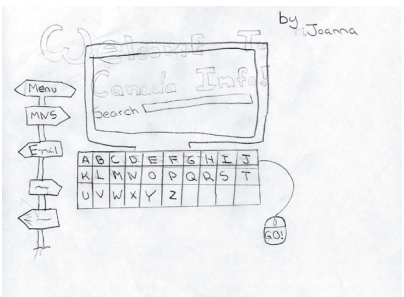

FIGURE 4.
Grade three drawing of a web portal, using the metaphor of a computer.

Demonstrations

As mentioned above, both the grade-six and grade-three design teams explored numerous web portals created for both adults and children. This was a collaborative group activity. The project used a laptop with a 19-inch screen, large enough for everyone to see, and a remote mouse and keyboard that permitted us to push the screen into the middle of the table so all could view it. This allowed everyone to participate. While only one child at a time could be at the controls, the rest of the group viewed and critiqued each portal. In the interests of fairness and harmony, the adult team members had identified enough portals in advance in order to allow everyone to take a turn at the controls.

Surveys

After the first session in the design process, the grade-six students conducted a "needs assessment" amongst their fellow students by taking a small questionnaire about web portals out to the school yard during recess. One important question asked was "what do kids like the most and the least about using the Internet for a school project?" This exercise served three purposes. First of all, it gave meaning to the children's work on the design team, making it "real" to them. Second, it was a focus-forming exercise, helping to define their purpose. Third, and in the context of our community of designers, most importantly, it provided a launch pad for group discussion about what children want to see in their web portals. During the second session, we did in fact spend time discussing the results of the survey, which showed the children that their peers wanted portals that worked fast and worked accurately.

Setting an agenda for discussion

At the start of each session, the adult team members outlined two to three topics for discussion in order to give the design team a sense of purpose. This strategy served to keep the younger members "on task" and, perhaps more importantly, provide a scaffold for expanding the way they thought about web portals for school. In several preliminary (pilot) design sessions held with small numbers of grade-three and grade-six students to refine our design methodology, we had seen that when asked to design a web portal on paper, children focused almost exclusively on entertainment features like music downloads, pictures of celebrities, or information about sports or television shows. The children in our design teams, especially the grade-three students, had never thought about a web portal as an information retrieval tool in the context of school-related activities. On their own, they may not have focused their thoughts on these aspects of portal design. It was therefore necessary for the adult team members to act as the "knowledgeable others" and provide structure to the process.

Seating arrangements

Gender differentiation was clearly present in the grade-six team when, during the first session, the girls sat at one end of the table and the boys at the other, presenting the possibility of two gender-based teams developing. Collaboration is central to the Zone of Proximal Development and so, to circumvent the problem of gender division, the adult team members dispersed themselves around the table between two girls or two boys. This helped to create a sense of unity amongst all.

Conclusion

Bonded Design is located in the Zone of Proximal Development and offers a framework for eliciting responses from children on abstract information retrieval issues. In our intergenerational design team, working together in the Zone of Proximal Development meant using collaborative activities in order to integrate children's unique perspectives with the specific problems associated with portal design.

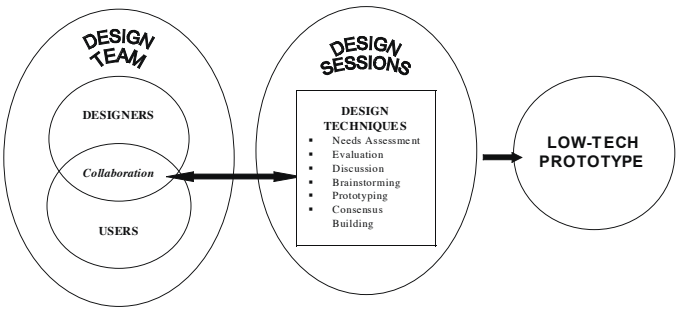

FIGURE 5. The Bonded Design model

Bonded Design is not the only way to design children's interfaces, nor is it necessarily a better way to accomplish this task. Nevertheless, an indication of the efficacy of the Bonded Design methodology is the fact that the research project reached and exceeded its objective. Not only were we able to design two low-tech prototypes in a relatively short period of time, and then to convert them into working high-tech web portals that can be used by children, but both portals subsequently have garnered very positive feedback from grade-three and grade-six students who have used them to find information on the Web (Large et al., 2005). They appreciated such attributes as the clear design of both the information search and information display screens, the opportunity to personalize aspects of the interface, the history quizzes directly accessible from the portal, the variety of search and browse retrieval tools incorporated especially in the grade-six team portal, and keyword spell

checking. They found it easier to use a portal whose focus was limited to one subject – history – and which retrieved only web sites whose content and language made them appropriate for young readers. Perhaps above all, the child evaluators welcomed a portal that reflected their cognitive and affective needs, in contrast to the "adult" portals such as Google and Yahoo with which they were familiar (Large et al., 2006a).

What, then, is the essence of Bonded Design? It is a means of bringing together for interface design purposes a team that unites in diversity: adult experts in interface design and child experts in being children. Like Cooperative Inquiry, it emphasizes an intergenerational partnership in working towards a common goal and shares with it the idea that children should play an active role in design rather than merely being evaluators or testers at the end of the design process. It does question, however, the nature of the cooperation between adults and children within the team, and in this respect shares some of Scaife and his colleagues' reservations concerning the extent to which true equality can exist within an intergenerational team (Scaife, et al., 1997). At the same time, however, Bonded Design differs importantly from Informant Design in its inclusion of children throughout the design process and as full team members. It also rejects Scaife's view that children are most helpful at suggesting ideas only for motivational and fun aspects.

Bonded Design also shares aspects of Learner-Centered Design in that it provides a learning environment for all team members – children and adults alike. Learner-Centered Design assumes that everyone is a learner, whether a professional or a student. In fact, Soloway and his colleagues describe professionals as "students who happen to learn outside of a classroom" (Soloway, Guzdial & Hay, 1994, p. 39). In designing web portals for children, as in Learner-Centered Design, the team's objective was to ensure that the design was adapted to the interests, knowledge, and styles of its target users.

Bonded Design draws upon ideas from several other design methodologies. From conventional User-Centered Design it takes the most basic premise – involving users. From Contextual Design were borrowed the ideas of drawing paper prototypes and a similar process to what it terms work redesign in the use of a white board to set out a map at the beginning of each session for what had already been accomplished and what remained to be done. Participatory Design provided the concept of peer co-designers, drawings (low-tech prototyping), hands-on activities and "learning by doing." Learner-Centered Design contributed the idea that all team members were learners. Informant Design supported the approach of seeking new and creative ideas rather than merely confirming what the adults already knew. The researchers also shared some of the reservations voiced in Informant Design about the true equality of children alongside adults in a design team. Cooperative Inquiry was followed in the central focus upon intergenerational team design and the

involvement of children from the start to finish of the design process. Bonded Design only approximates to rapid prototyping in those instances when the latter draws the user in at the earliest phases of the design process, before a prototype has been built, in order to identify the intended audience and establish the goals and objectives of the project. Like User Design, Bonded Design engages users in the design process, distributing power relationships between experts and novices, but in the former design method, unlike the latter, the purpose and goals of design projects are initiated from top down (in this context, from the adults to the children).

Essentially, then, Bonded Design is situated between Cooperative Inquiry and Informant Design. It shares the former's belief in the ability of children to work as partners in all aspects of the design process, but has reservations about the extent to which full and equal cooperation can occur across the generational divide, and in these respects, therefore, has similarities with the latter. What is noteworthy about Bonded Design? It is a proven means of developing technology that is authentic to young users, and can be accomplished in a relatively short time period and with minimal resources and costs.

Some of the lessons we as the adult researchers learned relate specifically to the grade-three design team rather than the grade-six team; the younger group needing more scaffolding from the adults than the students in the older group. Adult members of such design teams need to use a wider array of strategies to elicit discussion from young children. Future intergenerational design teams might consider using models from the field of education that are designed to provoke zones of proximal development. Two such examples are reciprocal teaching (a method of cooperative learning that uses specific question-prompts as a way to arrive at meaning) (Palincsar & Brown, 1984) and jigsaw (a method where tasks are divided amongst members and then shared with the group, such that each member becomes a piece of the puzzle – hence "jigsaw") (Aronson & Patnoe, 1997). These participant structures are familiar to children in today's classrooms and would therefore be relatively easy to implement within the boundaries of the design team.

At the heart of the Bonded Design methodology lies our "separate but equal" approach, reflected in the expert/novice relationship between the children and adult design team members. The children were experts in childhood but novices in information retrieval. The children on our intergenerational design teams played an active role in the process, providing input that went beyond the scope of their traditional recreational interests. Their input, however, evolved from the interplay between adult and child and not due to some innate knowledge that the children might have had about web portals. In this respect we view the design process as one where the expertise of the adults is needed by the children in order to progress. Nor would the

adults' input have been of use had the children not tempered it with their own expertise – their unique perspectives on childhood. By drawing upon this bi-directional expert/novice relationship, we were thus able to build a community of designers.

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