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Children and Adults Working Together in the Zone of Proximal Development: A Theory for User-Centered Design

Abstract:

This paper explores the theory of a zone of proximal development from the perspective of usability research and user-centered approaches to the design of information retrieval systems. Using concrete examples (dialogue, tools and techniques) from the inter-generational design teams of Large et al, this study will show how structuring usability research around Vygotsky's theory of a zone of proximal development can offer a robust conceptual framework for eliciting responses from children on information retrieval issues and for defining the role that children can play in the design process.

Résumé : Cet article présente la théorie de la zone prochaine de développement à partir de la perspective de la convivialité de la recherche et des approches orientées utilisateurs pour la conception de systèmes de recherche d'information. Utilisant des exemples concrets (dialogue, outils et techniques) tirés des équipes de conception intergénérationnelles de Large et al., cette étude démontrera comment la structuration de la convivialité de la recherche autour de la théorie de la zone prochaine de développement de Vygotsky peut offrir une cadre conceptuel robuste pour la sollicitation de réactions des enfants au sujet de la recherche d'information et pour la définition du rôle que les enfants peuvent jouer dans le processus de conception.

1. Introduction

Children are novices at life, but experts in childhood. Designers of information systems are almost universally adults who have expertise in information technology but whose childhoods are, regretfully, behind them and very difficult to recall with accuracy or authenticity. Children's motivations, perceptions, ways of organizing and retrieving information remain hidden to designers within a black box called "childhood". Usability research by Large et al tried to open this box through an intergenerational design process originally based on three user-centered design theories - Contextual Inquiry, Participatory Design, and Cooperative Inquiry - in order to integrate the specific expertise of children and the adult team members into two functioning web portals for children (Large et al, 2003, 2004). The concrete results of the implementation of these design theories were two low-tech web portal prototypes, that were subsequently transformed into working portals. (See Large et al, 2005, for the preliminary evaluations of the portals).

Connecting theory to method in the study of design is a useful exercise because it can shed light on the rationale underlying the process, explain outcomes or help set the stage

for further development. In the case of the work by Large et al, Contextual Inquiry, Participatory Design, and Cooperative Inquiry were early on identified as providing a conceptual framework for the specific techniques and methods used during the intergenerational design process. Subsequent analysis of results in the Large et al study pointed to certain modifications to these theories (see Large et al, 2005 for further elaboration). However, in order to enrich our understanding of the design process, we might also look at the process using another conceptual perspective - one that draws from theories of cognition, learning and child development. One such perspective is the theory of the zone of proximal development, a sociocultural approach to knowledge development (Vygotsky, 1978; Wood,1998). This paper will explore the zone of proximal development from the perspective of usability research and user-centered approaches to the design of information retrieval systems. Using concrete examples (dialogue, tools and techniques) from the inter-generational design teams of Large et al, this study will show how structuring usability research around the theory of a zone of proximal development can offer a robust conceptual framework for eliciting responses from children on abstract information retrieval issues and for defining the role that children can play in the design process.

2. Background

The research project reported in this paper has been grounded by an assumption that children approach the Web differently from adults, a belief that has a basis in existing research. A growing number of studies are finding that primary and middle school students, although often enthusiastic users of web portals, typically 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). It seems then that designing portals that are more in line with the affective and cognitive needs of their young users is essential in order to make information resources on the Web accessible to children. One way to achieve this may be to involve children in the design process. To explore this proposition, two inter-generational design teams, one comprised of eight grade-six students and three adult researchers, the other six grade-three students and the same three adult researchers, worked together over the course of six weeks to build two low-tech web portal prototypes. As they met twice weekly, the two design teams constructed the components to "their" portals piece by piece, through exploration, negotiation, questioning, brainstorming and sometimes heated debate. The final products, two low-tech web portal prototypes (meaning, the graphic versions, not the web-based versions), are shown in Figures 1 and 2.

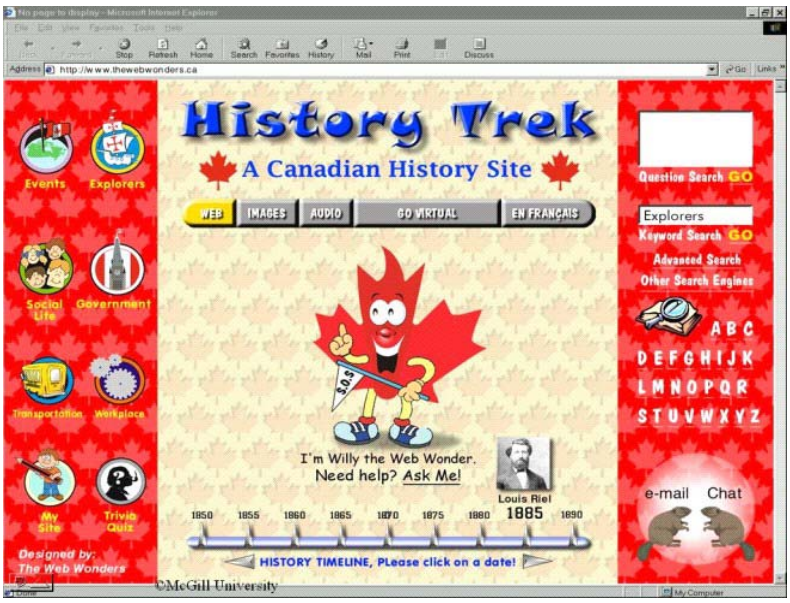

Figure 1. Grade-six low-tech web portal prototype.

Figure 2. Grade-three low-tech web portal prototype

3. The Zone of Proximal Development

This paper looks at the design process through the lens of a developmental theory, called the *zone of proximal development*. This theory was first articulated in the 1930's by Soviet psychologist, Lev Vygotsky. Vygotsky's ideas were viewed as anti-Marxist and, following Vygotsky's early death in 1934 from tuberculosis, his ideas were suppressed until 1958, only finding their way back to the research community in the late 1970's. Despite lying dormant for so many years, Vygotsky's theories of cognitive development

have had a profound effect on education in Russia, as well as the United States and Canada, helping to shape theories of teaching and learning in each country.

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 through interactions with more knowledgeable others. The zone of proximal development is often contrasted with Piaget's developmental model. While Piaget set limits to the boundaries of child development, Vygotsky expanded boundaries. 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.

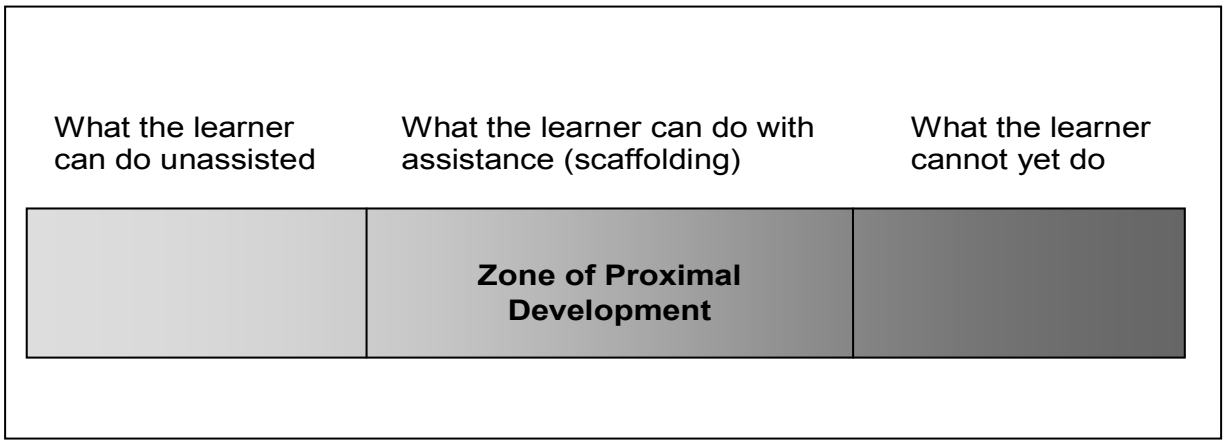

Figure 3: The Zone of Proximal Development

An example from Vygotsky to illustrate the point: Imagine two children, both aged eight, given the same problem to solve. Each is shown various ways of solving the problem by a more knowledgeable person, perhaps a teacher, a parent or an older sibling. With such assistance, one child is able to solve a problem classified at a 12-year-old level, the second can only work up to a nine-year-old level. In each case, the child has extended his or her thinking beyond the expected developmental stage. As well, this extension was reached within a social context (1978, 86).

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. The term scaffolding is a metaphor for the processes by which a more competent person assists someone less competent to solve a problem or carry out a task which the latter would not be able to complete alone. It can be adjusted and modified by the expert participant according to the novice's needs. Unlike Piaget, 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, Y. & Haywood, H.C, 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, A. & French, L.,1979; Brown, A. & Palincsar, A.,1987; Brown, A.L. & Campione, J.C., 1990; Brown, A., Metz, K. & Campione, J., 1996). One of goals 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.

4. Applications of the ZPD in the field of Library and Information Science

Although Vygotsky's zone of proximal development has been most associated with school settings, application of this theory has spread to other contexts. A wide range of studies have focused on the interactions between mothers and their preschool children in language development tasks, leading to theories related to emergent and family literacy. (Strickland, D. & Morrow, L. M., 1989; Morrow, 1997; Kermani & Brenner, 2000). These theories have had a direct impact on library services to children, providing a rationale for the extension of literacy promotion beyond the traditional three to five year-old storytime programs. Parent-child storytimes, Family Literacy Day, Mother Goose programs – all are based on the Vygotskian view of development: mental growth occurs in social contexts and potential development is more critical that actual development.

From the area of reference and library instruction we have seen a limited application of this Vygotskian theory as well. Carol Kuhlthau's notion of the *zone of intervention*, defined as "that area in which an information user can do with advice and assistance what he or she cannot do alone or can do only with great difficulty" is directly modeled on the theory of a zone of proximal learning. (Kuhlthau, 2004, 129). Kuhlthau has used the theory as a tool for helping librarians to diagnose when to intervene during the information search process, saying that intervention when an information seeker is self-sufficient is unnecessary and even intrusive and annoying, while intervention when a person can only proceed with great difficulty is enabling and enriching. (1994).

5. Web portal design and the ZPD: A community of designers

When Brown and Palinscar 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 inter-generational team consisting of adults with special knowledge in technology 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 inter-generational design team was indeed a community. We met regularly during the children's lunch period, an unstructured time of day for most students. Meetings were held nine times with the grade three students and thirteen times with the older grade six group. 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 first name. 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 community 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 will focus on two aspects of the interaction between members: 1) dialogue and 2) the tools and techniques used to launch discussion.

6. Dialogue:

Dialogue lies at the heart of the zone of proximal development, typically framed within collaborative activities. Dialogue in an inter-generational 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 inter-generational 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 user's (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 should work on a portal for finding information for school. 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 for grade-six low-tech prototype)

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 web portals – Google, Yahooligans!, KidsClick and Lycoszone – and while doing so, 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? 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 spelling was a theme that emerged early on in our questioning of grade-three students about web portals. 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 missing that day) and, by consensus, in the final low-tech prototype (see Figure 2 for grade-three low-tech prototype).

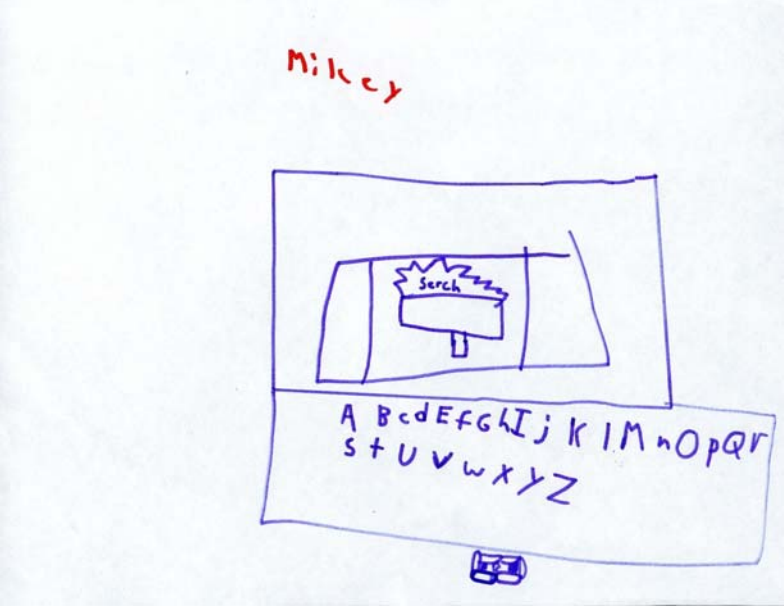

Figure 4: Drawing of a portal by grade-three student, showing "ways to find information" such as keyword search and alphabetical search.

The reader will recall that Vygotsky believed that development occurs most rapidly when children collaborate with others within his or her 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 using a brief survey which 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 grade-six and grade-three, 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 well-known 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 (which the children thought was too young for them due to the pictures). Another explored an experimental portal through PubMed which uses a concept mapping approach (this they found "too old" because of the complexity of the mapping).

7. 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 premiere method of eliciting discussion about design when working with children in an inter-generational team. Drawing serves many purposes when working in the zone of proximal development. In the case of our design teams, drawing 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 their picture to the rest of the group. This "show and tell" procedure provided an excellent forum for the sharing of new ideas. Ideas from the adult "experts" in portal construction sometimes 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 a timeline in a drawing of a portal for 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: Grade 6 low-tech web portal prototype)

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 with 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 below in Figure 5) 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)

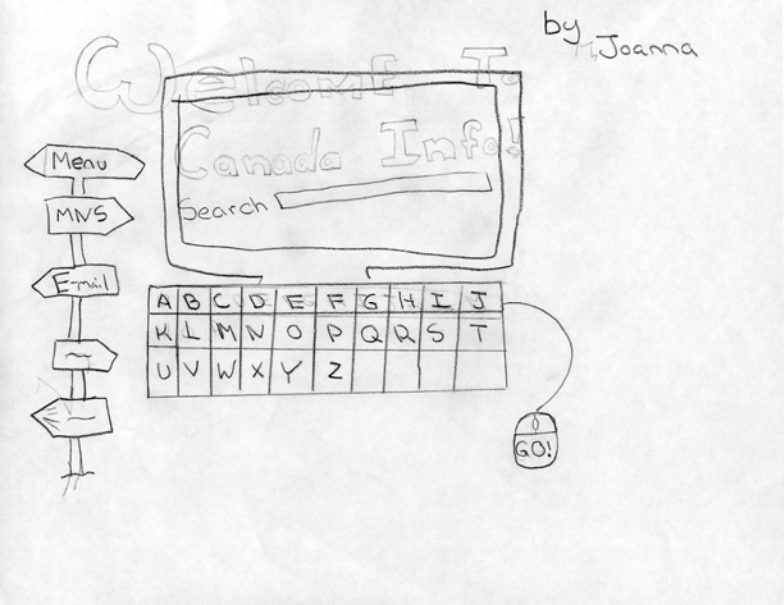

Figure 5: Grade three drawing of a web portal, using the metaphor of a computer.

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. Secondly, it was a focus-forming exercise, helping to define their purpose. Thirdly, 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 earlier focus groups, 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 not had occasion to think about a web portal as an information retrieval tool nor 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 key to the zone of proximal development and so, to circumvent the problem of two teams developing, 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.

8. Conclusion

The theory of the zone of proximal development offers a framework for eliciting responses from children on abstract information retrieval issues. In our inter-generational 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. 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 seeming to need 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 inter-generational 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) 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"). 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.

The children on our inter-generational 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 due 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. In other writings, we have described this methodology as Bonded Design, an approach to web portal design which is theoretically compatible to the theory of a zone of proximal development. (for a more complete description of Bonded Design see Large et al, 2005).

Web design teams are inherently social structures, sharing all the complexities (and pleasures) we normally experience when working collaboratively in a group. Add to this the unique challenge of uniting adults and children into one working unit and it is clear that the matter is not so straightforward. It is thus all the more important to understand the mechanisms that underlie the process.

9. Acknowledgements

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10. References

Bowler, L., Large, A. & Resjkind, G. (2001). Primary school students assessing, interpreting and using content on the Web. *Education for Information* 19 (3), 201-223.

Brown, A.L. & Campione, J.C. (1990). Communities of learning and thinking, or a context by any other name. In D.Kuhn (ed.) *Developmental perspectives on teaching and learning thinking skills*. Vol.21 in the series Contributions to human development. Karger: London, 108-126.

Brown, A. & French, L. (1979). *The zone of potential development: Implications for intelligence testing in the year 2000.* Center for the Study of Reading: Technical Report No. 128. University of Illinois at Urbana-Champaign, 1-38.

Brown, A., Metz, K. & Campione, J. (1996). Social interaction and individual understanding in a community of learners: The influence of Piaget and Vygotsky. In, Tryphon, A. & Vonèche, J. (Eds.). *Piaget-Vygotsky: The Social genesis of thought*. Hove: Psychology Press.

Brown, A. & Palincsar, A. (1987). Reciprocal teaching of comprehension strategies: A natural history of one program for enhancing learning. In, J. D. Day & J. G. Borkowski (Eds). *Intelligence and exceptionality: New directions for theory, assessment, and instructional practices*. Norwood, N.J.: Ablex Publishing. 81-131.

Fidel, R., Davies, R., Douglass, M., Holder, J., Hopkins, C., Kushner, E., Miyagishima, B., and Toney, C. (1999). A visit to the information mall: Web searching behavior of high school students. *Journal of the American Society for Information Science*, 50 (1), 24-37.

Hirsh, S.G. (1999). Children's relevance criteria and information seeking on electronic resources. *Journal of the American Society for Information Science*, 50 (14), 1265-1283.

Karpov, Y. & Haywood, H.C. (1998). Two ways to elaborate Vygotsky's concept of mediation: Implications for instruction. *American Psychologist*. January, 27-36.

Kermani, H. & Brenner, M. (2000). Maternal scaffolding in the child's zone of proximal development across tasks: Cross-cultural perspectives. *Journal of Research in Childhood Education*. 15, 30-52.

Kuhlthau, C. (1994). Students and the information search process: Zones of intervention for librarians. *Advances in Librarianship*, v. 18, 57-72.

Kuhlthau, C. (2004). Seeking meaning: A process approach to library and information services. Westport, Connecticut: Libraries Unlimited.

Large, A., Beheshti, J. & Moukdad, H. (1999). Information seeking on the Web: navigational skills of grade-six primary school students. *Proceedings of the 62nd Annual Meeting of the American Society for Information Science, Washington D.C., 31 October-4 Nov 1999* . Medford: Information Today, 84-97.

Large, A., Beheshti, J., Nesset, V. & Bowler, L. (2003). Children as designers of Web portals. *Humanizing Information Technology: From Ideas to Bits and Back. Proceedings of the 66th Annual Meeting of the American Society for Information Science and Technology*. Long Beach, CA (pp. 142-149). Medford, NJ: Information Today.

Large, A., Beheshti, J., Nesset, V. & Bowler, L. (2004). Designing web portals in intergenerational teams: Two prototype portals for elementary school students. Journal of the American Society for Information Science and Technology, 55(13): 1-15.

Large, A., Beheshti, J., Nesset, V., & Bowler, L. (2005). Web portal characteristics: Children as designers and evaluators. *Data, Information, and Knowledge in a Networked World. Proceedings of ….CAIS???*

Morrow, L.M. (1997). *Literacy development in the early years*. Boston: Allyn & Bacon.

Nesset, V. & Large, A. (2004). Children in the information technology design process: A review of theories and their applications. *Library and Information Science Research*. 26: 140-161.

Schachter, J., Chung, G.K.W.K. & Dorr, A. (1998). Children's Internet searching on complex problems: performance and process analyses. *Journal of the American Society for Information Science* 49 (9), 840-849.

Strickland, D. & Morrow, L. M. (eds.) (1989). *Emerging Literacy: Young Children Learn to Read and Write*. Newark, NJ: International Reading Association.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wallace, R.M., Kupperman, J., Krajcik, J. & Soloway, E. (2000). Science on the Web: students online in a sixth-grade classroom. *Journal of the Learning Sciences* 9 (1), 75-104.

Wood, D. (1998). *How children think and learn: The social contexts of cognitive development*. 2nd ed. Malden, MA: Blackwell.