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Developmentally Appropriate Digital Environments for Young Children

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Abstract

The developmental level of child information seekers affects their ability to interact with digital technology as a means to satisfy their information needs. Principles of child development and learning that inform developmentally appropriate practice must be considered when designing digital environments for the very young. Cognitive, physical, social, and emotional development impact a child's ability to interact successfully with a digital environment. These developmental considerations and design responses supportive of young children's information-seeking behavior, as well as perspectives of theorists in the area of child development and system design, are addressed.

Introduction

Today's child is brought up in the omnipresence of technology. A child may be exposed to digital technology even before he or she is exposed to books. Whereas the child of the recent past may have needed an introduction to computers and digital information upon beginning formal schooling, these things have very likely been a part of life for today's child from the beginning. One way that children learn is by observing their parents. Today's child may see his/her parents using computer technology more often than reading books. Digital technology has the potential to seduce young children with color, movement, sound, and interaction. It responds to a child's input in a most immediate and satisfying way. It empowers the child to make things happen instantaneously.

Given the ubiquitous nature of digital information and its significance in our culture as a means of communication, information getting,

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entertainment, and creative expression, it is important that children receive sufficient opportunities and appropriate experiences in its use. In our culture, digital technology is a tool for learning in much the same way as a pencil and paper; therefore, children need to gain facility in its use (Haugland, 1992). Knowledge and skill in this area are essential in order for children to successfully negotiate our culture. Unlike a pencil, however, digital environments have the potential to impose themselves more on a child through spoken words and moving images. Early exposure and availability of digital environments, both at home and school, make addressing design considerations for young children imperative (Liu, 1996). Computer technology, like any other tool, can be used appropriately or misused. Therefore, it is important that we use criteria when examining digital environments for children just as we would for any other learning tool or experience for children (National Association for the Education of Young Children [NAEYC], 1997).

Principles of Child Development

Domains of Development

The National Association for the Education of Young Children (NAEYC) has articulated a position statement on principles of child development and learning that inform developmentally appropriate practice (NAEYC, 1997). Child development encompasses several domains: cognitive, social, physical, and emotional. These domains are closely related in that they overlap and influence each other. While the following pages will address these different domains as they relate to digital design, it is important to remember that the domains are interwoven within the child; while we may discuss each domain as a separate entity for the sake of clarity, in reality they are interlocking facets of a whole. For example, the development of oral communication in a child involves the cognitive domain in that understanding and language learning are necessary. It involves the physical domain in that the child must gain control of mouth muscles and breathing in order to correctly pronounce words. It involves the social domain in that it requires subjective language use in order to understand and be understood in a particular culture. It involves the emotional domain in that relationships with other people are built and maintained through oral communication. Growth in each of these domains influences the other. As a child becomes more adept at oral communication, s/he is able to develop social relationships. The ability to communicate orally with other people supports cognitive development in that the child will learn from other people. Developmentally appropriate practice recognizes this intertwining of domains, and experiences are designed to support and optimize growth across domains (NAEYC, 1997).

Developmental Sequence

Development occurs in a relatively ordered sequence, and later abilities, skills, and knowledge build on previous ones (NAEYC, 1997; Piaget & Inhelder, 1969; Erickson, 1963; Bruner, 1973). Kuhlthau (1988) has commented that children's information needs relate to their developmental level. Studies show that children as young as three years old can use computers (Liu, 1996). Children younger than three years old are still in Piaget's sensory motor stage of development, during which they learn through their senses by tasting, touching, and crawling; at this stage they are not good candidates for computer use (Haugland, 2000). Children who are in preschool or primary school are most likely in Piaget's pre-operational stage of development (Piaget & Inhelder, 1969). They understand the world from their own point of view. They are individualistic, self-centered, and expect others to have their perspective. This does not bode well for the use, for example, of a highly structured digital environment even if these children could read well enough to understand the directions for use (Cooper, 1997). Piaget's concrete operational stage follows pre-operation. Children are in approximately second or third grade by this time. They use trial and error and depend on manipulation of physical items to solve problems. Their understanding of concepts such as change and comparison is physical rather than abstract. Since their understanding is still grounded in what is concrete and physical, they may have difficulty using electronic metadata even if they can read the directions and move between screens (Cooper, 2002a). A list of alphabet citations may mean much less to children at this level than an electronic display of familiar book covers. While a digital representation of book covers is not concrete, there is an observable reference to that which children have experienced concretely and understand.

Another perspective on sequential development is offered by Erickson (1963) in his stages of psychosocial development. Children in kindergarten may still be in Erickson's stage of initiative vs. guilt. They want to explore but at the same time they want to please. They are moving toward the ability to use structured systems. An early elementary child may be in Erickson's industry vs. inferiority stage and learning to master more formal competencies. Each of these stages requires emotional support and a feeling of success and increasing confidence if the child is to move toward maturity in the emotional domain. Digital environments with built-in safety nets such as spell check are supportive of emotional development as well as cognitive development. Kuhlthau's (1993) Information Search Process includes significant examination of the affective nature of information seeking. These feelings are compounded for the very young because developmentally they lack the cognitive ability, physical coordination, and social experience that older information seekers have. Likewise, Belkin's (1980) Anomalous State of Knowledge may be more keenly felt by young children since they have a significantly smaller stock of knowledge and experience on which to base a question that will satisfactorily relate their information need. Their vocabulary is too small to express what they know they need to know.

Varying Rates of Development

While developmental stages occur in an ordered progression and new skills are dependent on old skills, the rate at which each child develops differs. In addition, an individual child can progress through different domains at different rates (NAEYC, 1997). That is, not only do different children develop at different rates, but an individual child may progress unevenly within different domains. For example, a child may have a highly developed sense of kinetics, spatial relationships, and fine motor skills. The same child may experience language difficulty. Children at the same developmental level may have different ways of knowing and learning and different ways of demonstrating what they know (Vandergrift, 1996; Gardner, 1999). Each child is unique and "variation is not only to be expected but also valued" (NAEYC, 1997). Children's skill in spelling, typing, spacing, punctuation, syntax, alphabetization, scanning, and tracking may vary (Busey & Doerr, 1993). Children in the same class at school may differ in their ability to decode, follow directions, and stay on task. In order to accommodate varying developmental rates, learning styles, and preferences of children in the same class who share hardware and software, systems should have, for example, the option of keyboarding or point and click navigation.

Learning as Building

Development moves toward greater complexity, from "behavioral knowledge" toward "symbolic or representational knowledge" (NAEYC, 1997). Learning is a building process—children need a previously existing knowledge and experiential base on which to scaffold new information if it is to have meaning to them (Bruner, 1973). For example, for very young children who may have little experience with digital environments, an interface that mimics real life through the use of graphics is supportive of a young child's developmental needs. Pejterson (1989), Borgman, Hirsh, Walter, and Gallagher (1995), and Cooper (2002b) used graphic representations of a bookshelf when working with children.

Children need to broaden and deepen the knowledge they already have, and they need the opportunity to relate this new information to something in their experience that they already understand (NAEYC, 1997). They need both the challenge of new experience and the opportunity to practice skills they already possess. Vygotsky's 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). A variation of this is Kuhlthau's Zone of Intervention, "that area in which a user can do with guidance and assistance what he or she could not do alone" in the Information Search Process (Kuhlthau, 1993, p. 176). Developmentally appropriate digital environments for children support both mastery of knowledge and growth. Play is an important part of a child's social, emotional, physical, and cognitive development. It gives the child an opportunity to practice new skills and construct meaning without risk (NAEYC, 1997). Play is important because it enables children to become familiar with materials and concepts. Play becomes even more valuable when it offers feedback that the child can interpret (Bowman & Beyer, 1994).

Biology and Environment

Development and learning are affected by both biological and environmental influences. Environmental influences include those that are physical and those that are sociocultural. In terms of design and use of digital environments, at a certain developmental level a child's fine motor abilities will enable him or her to manipulate a mouse and thus move between computer screens by holding the curser over a point and moving their finger to click that point. Difficulty with this action may be due to immaturity of muscles needed in fine motor coordination or to lack of experience using a mouse because the child does not own a computer, because no one has taught him how to use one, or because his school cannot afford the hardware and software. A child may also have trouble moving between screens because she cannot read alphabetic directions or icons. Her trouble with reading may be due to a biological issue (cognitively she cannot yet relate the abstract symbols to sounds and concepts) or an environmental issue (no one has taught her to read). The particular technology that has been designed to serve as a tool toward information for a child at any developmental level needs to take multiple factors into consideration. A digitally presented story for kindergarten children may have understandable graphics, but if moving through the story necessitates a degree of fine motor coordination that is uncharacteristic for a five year old, a kindergarten child might not be able to negotiate the story. Conversely, a child may have the fine motor ability necessary to use a mouse, position a cursor over a point, and click, but if the symbols she needs to negotiate are unintelligible to her she will not progress through the story.

Vygotsky (1978) tells us that our culture not only provides us with information but teaches us how to understand that information. The link between concept and signifier—with word or icon—is arbitrary and governed by community choice. A child raised in an environment that is rich in the use of printed language and/or graphics will be more facile with these at an earlier age than a child who does not have these experiences (Cooper 2002c, 2002d). Aspects of the digital environment, such as color, size, relationship of graphics, and figure-ground relationships, may be interpreted differently

(Cooper 2002c, 2002d). Even our understanding of how knowledge is interrelated is culturally based. The Dewey Decimal System, according to which most of the public libraries in the United States are organized, is a cultural interpretation of how knowledge is interrelated (Cooper, 2004).

Research by Eleanor Rosch (1975) and Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976) on basic level category members and goodness of example impacts the design of digital environments for children. The basic level is the first category level to be named by children, the first to enter the lexicon of a language, and that level which has the most commonly used label for category members (Lakoff, 1986). For example, the word "dog" is the basic level member of the larger category of canines. "Canines" is broad, "Labrador Retriever" is narrow; "dog" is most readily understood by children. In addition, Rosch's research in goodness of example category members further supports the development of digital environments appropriate for children. Some category members are better examples than others of that category. A robin is a better example of a bird than a penguin, so the more effective graphic to represent the concept "bird" would be a picture of a robin. This depends, of course, on the environment in which the child lives. Since children in grades kindergarten through grade two are nonreaders or just beginning to read, they may rely greatly on pictures for information. Pictorial literacy is a learned skill. Children tend to be literal in interpretation of graphics. They may understand information that pictures were never intended to convey. For example, they may respond as if an element in a picture does not exist or interpret figures as incomplete (Higgins, 1980). Their understanding is literal rather than representational, and they may not have the experience necessary to make the required inference. A child needs to learn how to read a picture in such a way that he knows specifically to which information it refers, to pay more attention to some aspects and less to others. Areas for consideration when using graphics with young children include levels of interpretation, context, sequence, pictorial literacy, part-whole perception, and emphasis (Goldsmith, 1984).

The Child as Active Participant

Principles of developmentally appropriate practice view the child as an active learner and participant in his or her own development (NAEYC, 1997). Reflection deepens knowledge and understanding (NAEYC, 1997). As new experiences and knowledge become available to the child, he scaffolds the new to the old in order to deepen and broaden his knowledge base. Children use their own physical and social experiences together with the knowledge transmitted to them by their culture to construct their personal understanding of the world. They learn in order to become members of their culture (Vygotsky, 1978), and in our culture facility in digital environments has become a necessity.

Design Responses

Developmentally appropriate digital environments are designed in keeping with principles of developmentally appropriate practice as described in the sections above. The following sections address design responses supportive of development in the various domains.

Cognitive Considerations and Design Responses

Learning to read may be the greatest cognitive challenge that young children face. Young children's understandings are largely concrete and sensory rather than abstract and symbolic. As they mature, they begin to understand the symbol use of their culture. The task of reading is made up of a series of steps. Children need to recognize alphabetic symbols and attach them to sounds. They need to decode symbols groups (words) and then read each word for meaning. They need to link together series of words (sentences) and read those for meaning as well. If a child is working in a digital environment, there may be links through which he must move, and he must understand the process and progression of moving through these links to the next appropriate screen of information. Developmentally appropriate digital environments for young children support the accomplishment of these steps.

Programs that read aloud in a clear, well-paced voice help young readers attach sounds to letters, syllables, and words. Repeated reading supports language development (International Reading Association and the National Association for the Education of Young Children, 1998). Programs that enable children to manipulate speech segments, either through letters or images, allow them to build words and stories of their own while learning language (Clements, 1994). Use of icons in conjunction with or instead of alphabetic symbols support children who cannot read or read well, have trouble scanning text on a computer screen, or have trouble with the concept that an alphabetic citation stands for a book that they want. Social interaction at computers, play, and self-narration by children encourage language development (Van Scoter, Ellis, & Railsback, 2001). Programs that help children not only to count, sort, identify, and match but also to notice relationships, predict cause and effect, understand properties, draw conclusions, and solve problems support cognitive growth for young children (Davidson & Wright, 1994). Children need to learn basic relationships, sequencing, and sensory properties such as light and heavy, before and after, day and night in order to communicate effectively (Elkind, 1999). Open-ended stories that children can construct allow them to work with these concepts. Environments that allow text to be entered easily and that feature spell check and built-in prompts allow the child user to focus his or her efforts on ideas and also to model correct mechanics (Clements, 1994). Prompts can also be helpful for a child who neglects to take "the next step" in a program. For example, if a program is idle for too long, a prompt might direct the child to take an action (Liu, 1996). Relating new concepts to those with which the child is already familiar can increase attention span and arouse interest (Liu, 1996). Such programs allow the child to scaffold new learning to an already existing knowledge base in a meaningful way. Assistance can then be gradually withdrawn (Clements & Sarama, 2003).

The sounds and images of interactive environments are intrinsically motivating to young children (Liu, 1996). Interactive programs empower children to construct their own information using sounds, images, and words. They allow children to hone decision-making skills, and they make the decision-making process more explicit for children (Char, 1990). Programs that allow children to write creatively; draw or paint; solve math problems; and manipulate shapes, patterns, and ideas are tools for thinking. Children are able to use the computer as a tool for creativity and problem solving as well as a means of reflection on the task they are performing (Bowman & Beyer, 1994).

Programs that are child controlled support different learning styles and paces (Liu, 1996). Children can repeat actions and processes and experiment with variations (NAEYC, 1996). Encouraging "children to reflect on experiences by planning beforehand and 'revisiting' afterward" helps to deepen the understanding gained from experience (NAEYC, 1997). Video or audio replay can encourage metacognition (Char, 1990; Cooper, 2002a). In addition, multiple intelligences (Gardner, 1999) are encouraged through the use of programs that support children's creative growth as well as logical and empirical thinking (Bowman & Beyer, 1994).

While passive, rote activities afford the opportunity to practice a skill, environments that support the development of higher-order thinking (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956) are desirable. Programs that pose challenging questions and encourage reasoning, predicting, imagining, and projecting support higher-order thinking (Downes, Arthur, & Beecher, 2001). Web quests can be vehicles to this end by posing problems that promote critical thinking and breaking tasks into manageable chunks that guide children through a process (Ferguson, 2001). Adult support and encouragement allow the child to move through the Zone of Proximal Development (Vygotsky, 1978) to accomplish a higher level of understanding than they would without this support. Programs should encourage children to reflect and ask questions. They should respond to children's input, offer variations that children can control, and support individual abilities and interests as well as various languages, experiences, and cultures (Downes, Arthur, & Beecher, 2001). The element of child control is particularly important because it supports the growth of facility with symbol systems. Children are thus able to connect symbols and relationships in ways that are most meaningful to them (Bowman & Beyer, 1994).

Social Considerations and Design Responses

Vygotsky (1978) tells us children learn in order to communicate with and become members of their culture. In our present culture, facility in digital environments is necessary for optimum communication. Indeed, computer communication is an important aspect of "social discourse" through which children come to understand the values and beliefs of their culture (Bowman & Beyer, 1994, p. 20). Computers have the potential to serve as "catalysts of social interaction" (Clements & Sarama, 2002, p. 1), thus supporting social development of children if used properly. Research has shown that children spend more time in conversation with peers while working on computers than they do when working with puzzles and that they show increased interest in collaborative efforts as well as an increase in helping, peer teaching, discussion, and building on other children's ideas (Clements & Sarama, 2002). Children gain knowledge about the social system through which ideas are symbolized as evidenced by the move from their own "idiosyncratic representations" to those representations employed by their community (Bowman & Beyer, 1994, p. 23). This is an important aspect of social as well as cognitive development since internalization of cultural meanings will enable children to function and participate as members of their community (Wertsch & Stone, 1985; Cooper, 2004).

The type of software used impacts the social interaction it engenders. For example, close-ended drill and practice types of software encourage turn taking. Open-ended software programs, on the other hand, encourage collaboration since the possibility of several solutions to a problem is cause for discussion (Clements & Sarama, 2002). In addition, open-ended programs support group goal setting, planning, negotiation, and resolution, as well as peer helping and teaching behaviors (Clements & Sarama, 2003) and responsible, reciprocal social relationships (Bowman & Beyer, 1994). "By asking questions and interacting with others through computer-related technology, students are able to understand more effectively than through traditional static methods such as textbooks and worksheets" (Ferguson, 2001, p. 48). Shared leadership and cooperation are enhanced (Van Scoter, Ellis, & Railsback, 2001).

"Griffin and Cole (1986) point out that the co-construction of knowledge that is possible through computer use in the international community may potentially change the framework of thought in different communities" (Bowman & Beyer, 1994, p. 23). Communication via the Internet supports both development of language skills in the cognitive domain and interrelationship skills in the social domain (Subrahmanyam, Kraut, Greenfield, & Gross, 2000; Bowman & Beyer, 1994). Supportive environments need to recognize differences in the experiential and cultural backgrounds of child users. Young children are most likely to understand information at the basic level (Rosch et al., 1976), and so examples used in digital environments should be appropriate to the audience. Depending on their background, young children may not have experience in focusing attention on the most important aspect of a visual display (Cooper, 2002c). A supportive design element may, therefore, draw attention to important areas via judicious use of color, sound, or movement. Images should be understandable to children. Consideration should be given to whether the child user is accustomed to “reading” information from left to right, right to left, or up and down. Care should be taken with the use of color having cultural connotations (Cooper 2002c; Pettersson, 1982).

Digital environments supportive of development in the social domain do not present stereotypes of people; rather they present diversity in culture, language, ethnicity, age, ability, and lifestyle (NAEYC, 1997). They present positive social values and are nonviolent. For example, mistakes are not “blown up,” but rather the child may be offered several ways to correct the mistake that are socially acceptable and realistic (NAEYC, 1997).

Situations that support the social development of children not only maximize social interaction and cooperation but afford equal access for all children (Appel & O’Gara, 2001). So, for example, permission to use open-ended programs supportive of higher-order thinking skills and social growth should not be awarded for good behavior or high academic achievement while low-achieving students are directed to drill and practice programs (NAEYC, 1997). Children vary in their developmental levels regarding cooperative behaviors, following directions, and ability to stay on task. Programs that encourage contributions from multiple members of a group to solve a problem allow children to have directions repeated/demonstrated either orally or visually and offer immediate feedback, positive reinforcement, and support for growth in these areas.

The physical environment in which children pursue the digital environment impacts the degree to which social development is supported. Ideally, there should be at least two seats in front of the computer screen. There should also be a seat to the side for a teacher or other supporting adult. When computers are placed close to each other, children are encouraged to share ideas. When computers are centrally located rather than isolated, other children are easily invited to participate and a teacher/adult can oversee without looming (Clements & Sarama, 2002). Clements, Natasi, and Swaminathan (1993), as reported by Bowman and Beyer (1994), suggest a sample activity in which children construct digitally generated drawings as a group. They discuss the relative size of the object produced by inserting various numbers into the program, and they visually connect the relationship between a number and an object size. They control the relationship themselves and thus learn about estimating. They also learn important social skills regarding cooperation to create a product and reach a goal (Bowman & Beyer, 1994).

Physical Considerations and Design Responses

Computer hardware and software afford multiple accommodations that support children who are not yet at a developmental level at which they can negotiate physical environments designed for adults. Children who are nonreaders, beginning readers, or emergent readers may not be able to track and scan text with ease. An overloaded screen may make it more difficult for a young child to focus on a particular area. The use of a larger font and readable font style as well as inclusion of less text and/or images on a page make it easier for children to address the information on the screen. Information should appear in both text and icon format (Liu, 1996). Use of color to help young children distinguish objects from each other on a screen, and uncomplicated shapes that are recognizable, also support the child viewer. Material on the screen should be presented in a clear and consistent manner throughout a program. Icons, text, buttons, and a Help area that appears in the same place on every screen make it easier for children to progress through a program (Liu, 1996).

Typing is a concrete activity that produces immediate results via both the confirming "click" of the keys and the visual symbol produced. Children need less fine motor coordination in typing than is necessary for writing and have the satisfaction of immediate gratification in seeing the results of their efforts (Clements & Sarama, 2002). Large keyboards make it easier for children to type without error (Liu, 1996). While some children are developmentally able to manipulate a mouse and move a cursor over a point and click, other children may not yet be ready to do this. Touch screens make it easier for children at different ability levels to interact with a digital environment. It is also more intuitive to touch a screen than to type a response or command (Liu, 1996). Accommodation of physical developmental needs for special needs children enables them to participate in group activities that equalize the "playing field" so that they can interact with their age peers (Clements & Sarama, 2002; Clements, 1999).

Emotional Considerations and Design Responses

"Children develop and learn best in the context of a community where they are safe and valued, their physical needs are met, and they feel psychologically secure" (NAEYC, 1997). Emotional development as it relates to Erickson's (1963) psychomotor levels of development, Kuhlthau's (1993) Information Search Process, and Belkin's (1980) Anomalous State of Knowledge have been addressed earlier in this article. In addition, Maslow (1998) offers a perspective on human needs in his hierarchy of needs relating to physiology, safety, love, esteem, and self-actualization. Children need a secure environment in which they can explore and develop without confusion, doubt, and fear of error (NAEYC, 1997). Environments that are supportive are those that offer the ability to avoid or correct errors, go back, review, hear or view again, and provide feedback so the child knows what is happening. For example, a blinking cursor will help a child to understand that a component is loading rather than thinking that she has made an error (Liu, 1996).

Research by Astleitner and Leutner (2000) in the area of emotions and affective considerations in children using digital environments suggests that fear, envy, anger, sympathy, and pleasure all influence a child's success in using technology. Their studies indicate that fear of failure can be assuaged by support measures that help ensure success, such as feedback, overviews, advance organizers, and self-checking mechanisms, as well as pace of instruction and reduction of task difficulty. In addition, offering methods to correct mistakes and giving the child the ability to turn mistakes into learning experiences also support the child emotionally. For example, they suggest that mistakes might be turned into a question-and-answer list to which students contribute, thereby helping others. Fear of failure may be lessened by giving children tools to organize information so that it is less overwhelming. These might include methods of putting information into hierarchies, databases, or spreadsheets. Students may also be encouraged to find patterns, rank ideas, develop timelines, categorize, and compare.

Astleitner and Leutner (2000) further suggest that envy may best be assuaged by limiting competition and comparison of children and/or their work. Care should be taken that anger does not spread or accumulate. Programs should be designed that allow anger to be expressed in a constructive manner that corrects unfair situations, monitors events, and leads to resolution. For example, use of an "anger button" that, when pressed, leads to a Help area may help students toward anger resolution. Students can be encouraged to be more flexible by offering links to other points of view concerning the same information (Astleitner & Leutner, 2000).

PETS, A Personal Electronic Teller of Stories (Druin et al., 1999), is a collaborative project in which adults and children work together to design a storytelling environment that uses robots controlled by elementary school children. Child designers identified six emotions that were incorporated into the design: happy, sad, lonely, loving, scared, and angry. Children can construct a robotic pet by connecting animal parts (for example, head, paws, etc.) and then use the animal to tell stories using My PETS software. The software enables them to incorporate emotions into their story by having the robot perform specific body movements. For example, if the robot is sad its body will droop. Children are always in control, and self-expression conveyed through the animal robot enables them to discuss "difficult emotional issues" (Montemayor, Druin, & Hendler, 1999).

Astleitner and Leutner (2000) note that some emotions are considered socially positive. To encourage sympathy, relationships can be intensified by making communication between children easier through email, listservs, or chat sessions. Cooperative learning structures such as groupware, integrated classroom management tools, application sharing, and low-level authoring tools through which contributions can be extended by other students also support relationship building. Enhanced well-being can be supported by activities that increase skills or are intrinsically satisfying. User-friendly environments support speedy connection and loading of pages, offer cues for users, and have clear selection areas, progress tracking, help areas, and short pages (Astleitner & Leutner, 2000). Student-controlled learning, use of humor, and play activities also support pleasurable experiences in digital environments. Student-directed learning also supports the development of autonomy in learning rather than always seeking authority (Clements, 1994). This, in turn, supports children as lifelong learners (American Association of School Librarians & Association for Educational Communications and Technology, 1998).

Summary and Closing Thoughts

As we have seen, experts in the area of child development (Appel & O'Gara, 2001; NAEYC, 1996; Davidson & Wright, 1994; Haugland, 2000; Downes, Arthur, & Beecher, 2001; Clements & Samara, 2003; Van Scoter, Ellis, & Railsback, 2001; Ferguson, 2001) suggest that developmentally appropriate digital environments should

- support the child as a unique individual;
- be child controlled;
- be open-ended rather than close-ended;
- be active rather than passive;
- involve many senses;
- encourage exploration, experimentation, and risk taking;
- encourage critical thinking, decision making, and problem solving;
- offer quick feedback, be interruptible, and keep records;
- balance familiarity with novelty;
- be user friendly;
- be progressively leveled, offering new challenges;
- be responsive to child input;
- build on previous learning;
- encourage reflection and metacognition;
- support social interaction.

Overall, these criteria are similar, if not the same, to those used for any developmentally appropriate material designed for young children. An often argued question is whether computer use contributes to or damages the education of young children. If, as noted above, developmentally appropriate digital environments can be evaluated by criteria similar to those of any other developmentally appropriate material for children, then the answer to this question is that "it depends." It depends on the material used, the circumstances of its use, and the way it is used. Most of all it depends on the readiness of the individual child for a particular environment. Even the most excellent nondigital material is not appropriate for all children. In this same way, even the most excellent digital material will not be appropriate for all children. Technology is a tool, not a solution. It is not "the answer," nor is it a panacea any more than a power tool is when we have trouble doing a job with a hand tool. One might even say that in the case of both computer technology and power tools, we can accomplish more and possibly better things, but there is also a potential for bigger mistakes. Technology is clearly not a substitute for human interaction and attention to the unique needs of each child, nor should it be the scapegoat when these things are not provided. However, attention to design that is developmentally appropriate and supportive of children's needs as exemplified by recent adult/child design collaborations (Druin, 2002; Bilal, 2003; Large, Beheshti, Nesset, & Bowler, 2003) moves us closer to a wiser, more enlightened implementation of technology as a tool for children's learning. The concept of children as design partners demonstrates a respect for their intelligence and creativity as well as increases the likelihood of usability and high interest level for children. Digital environments are tools that broaden and extend learning possibilities for children. An appropriate digital environment provides a vehicle that can take a child further than he or she might travel unassisted. Responsible and well-considered design and content choices in keeping with a child's developmental needs provide the basis of positive digital environments for children.

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