http://www.futureofchildren.org

Five Commentaries: Looking to the Future

To provide an array of perspectives about the role of computers in children's lives, we asked five experts across various disciplines and backgrounds to respond to this question: "How can we help ensure that computer technology is used equitably, effectively, and ethically to promote positive child development?" Their responses follow.

1 COMMENTARY

Milton Chen

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Equity is at the core of the question posed. Broadly speaking, technology cannot be used effectively or ethically *unless* it is used widely and equitably among all groups in our society and—thanks to technology itself—our increasingly smaller world. Equity of use is critical to ensuring that technology has widespread and effective impacts on learning, communication, and community. In addition, "equality of digital opportunity" is fast becoming a synonym for "equality of educational opportunity," central to our nation's ethic of democracy. Limiting the expanded opportunities of technology to groups with greater educational and financial resources would be unethical—and in the future, perhaps even unconstitutional. It is conceivable that within the next decade, parents might sue their school board for denying their children's rights to computers and the learning resources of the Internet.

Recognizing the importance of ensuring equitable access to computer technology, issues of the "digital divide"—and indeed the term itself—rapidly became part of our national agenda in 1999. Equitable use of computer technology was highlighted in January 2000 when President Bill Clinton included it in his State of the Union Address, and the topic has continued to be discussed throughout this election year.

Public debate must move beyond issues of simply providing children access to a computer at school or at home, however. As discussed in the article by Becker in this journal issue, because computer technology is constantly improving,[1] more refined measures of equitable access should include the power of the computer, the child-to-computer ratio, and the speed of Internet connectivity. Children with high-speed Internet lines and CD-ROM players have superior access to technology compared with children working with 28K modems and floppy disks.

In addition to the physical factors of the "boxes and wires" that provide technical access, discussions of equity should also include the psychological factors of a child's inner attitudes, motivation, and interest in computers.[2] Consider, for example, two teens who live in the same neighborhood, go to the same school, and have similar family backgrounds and socioeconomic status. One uses a community technology center to design Web sites for local businesses. Another has never stepped into this center. What accounts for the difference? Education is critical to providing greater "inner equity," to lighting the fire within children who view technology as an important and enjoyable way of learning and communicating.

Six Steps to Crossing the Digital Divide

Ensuring equitable use of computers by children requires a coordinated national approach that provides not only pervasive access to the technology, but also appealing content and compelling role models. The following six steps address both the machines and the motivation needed to encourage greater numbers of young people to cross the digital divide.

1. Strengthen National, State, and Local Leadership

Leaders in government, business, and education already are linking our highest education priorities to closing the digital divide.[3] These groups include elected officials, from the

President and members of Congress to governors and state legislators; community-based organizations such as the National Urban League; corporations such as AOL Time Warner and Gateway Computer; and foundations such as the Gates Learning Foundation and the Benton Foundation.

Leadership is needed to support creative public and private partnerships, as discussed in the article by Wartella and Jennings in this journal issue. These partnerships could lead to pooling expert resources—such as business volunteers to provide training—or to the creation of public-sector incentives to make community service more appealing to businesses—such as tax incentives for computer donations.

2. Provide Funding for Hardware, Software, and Connectivity

Although cost decreases are making computer technology more affordable,[4] government, business, and philanthropic organizations need to continue providing funds for technology purchases, maintenance, and network connectivity, especially in underserved communities. Federal E-rate legislation, as detailed in Appendix A by Roberts in this journal issue, has been valuable in making Internet connection more affordable for schools, libraries, universities, and community groups.[5] With the convergence of telephone, television, and computer into one box with one screen, continued support from legislation such as the E-rate can help ensure greater equity of use for these multiple services among families, schools, and communities.

Community technology centers (CTCs) in low-income neighborhoods offer one of the most promising solutions to the digital divide. One funding initiative from the U.S. Department of Education has provided more than $40 million to CTCs in public libraries, community organizations, and public housing facilities.[6] Instead of isolating individual children with computers in bedrooms, CTCs encourage children and adults to share their experiences and support each other within a community setting. A new report by The Children's Partnership on low-income Internet users describes the value of technology mentors who work with novice users in CTCs.[7] If computers and the Internet can bring people together and create new kinds of community arrangements, both in person and through virtual groups, the implications can be profound, merging "high tech" with "high touch."

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3. Improve Technology

Greater equity of availability and use is related not only to cost, but also to functionality. The past five years have brought significant advances in computer capability to present graphics, images, and sound—in addition to text—making the computer more appealing and useful to a broader group of users.

The next five years promise greater functionality in terms of video and artificial intelligence features, such as speech recognition and language translation. These improvements will contribute to a greater range of applications reaching an even greater user base. The ability to use the Internet to communicate in different languages via text, audio, and video, for example, will not only enfranchise the growing numbers of immigrant children and their families in the United States, but will also encourage communication between U.S. children and children around the world.

As discussed in the article by Hasselbring and Williams Glaser in this journal issue, devices such as text-to-speech readers, speech recognition, and special keyboards help adults and children with special needs use technology and thereby "level the technology playing field."[8] Furthermore, organizations that work with people with special needs, such as the Center for Applied Special Technology,[9] demonstrate how assistive technologies for specialized populations can help create more inclusive applications for all users. As these technologies develop, they will become more mainstream and be used by a majority of children. For example, speech recognition software, valuable to children with motor disabilities who cannot type using a keyboard, will benefit everyone.

4. Develop and Promote New Content

The recent Children's Partnership study of low-income Internet users found a shortage of useful online content.[7] Internet content must respond to the diversity of needs and interests among children—across age groups, gender, geography, and languages.

As the computer becomes a ubiquitous medium, its parallels to television are becoming clearer. The article by Wartella and Jennings in this journal issue discusses how television has failed to fulfill its promise of

being a "window on the world" for children. Underfunding and the scarce availability of educational content have contributed to this failure.[10] For digital television and the Web to make good on their promise, high-quality content that is widely promoted and accessible remains key. Some excellent examples of educational content are already available on the Web, such as the Exploratorium Web site for science (http://www.exploratorium.edu), the Library of Congress National Digital Library for history (http://www.loc.gov), MaMaMedia (http://www.mamamedia.com), and Sesame Workshop (http://www.sesameworkshop.org) for interactive children's content. More such Web sites are needed.

New forms of digital content hold the potential to more closely target children's ages and stages of development, as well as their interests, backgrounds, and locales. Just as educational television pioneered new formats and techniques for delivering educational content creatively,[11] new digital media are developing a field of digital information designed for children, as discussed in the article by Montgomery in this journal issue. These newer media can build on the knowledge base of the best of children's books, games, television, and software.

5. Provide Training for Teachers, Parents, and Other Caregivers

Another factor often cited as important to increasing equity is improved and widespread training for teachers, parents, staff of community organizations, and other adult caregivers. These key adults play important roles in facilitating and encouraging children's computer use. Funders are wisely tying grants for technology to the training of staff in schools and community centers. For instance, U.S. Department of Education grants provided to schools of education under the "Preparing Tomorrow's Teachers" program emphasize technology training for student teachers.

Two decades of computer use have shown how this technology is reversing generational knowledge and authority. These days, children often know more about computers than their parents and teachers do. Children and teens represent an important source of technology skill and expertise that should be harnessed for technology training.

"Generation Why" is an example of such a program. Originating in Olympia, Washington, and now expanding across the country, this program uses high school students to support teachers' use of technology. GenWhy students prepare instructors' PowerPoint or CD-ROM presentations or locate the best Web sites on a topic.[12] These younger students take on "teaching assistant" roles more common to university students. Because the best way to learn a subject is to help teach it, both teachers and students can benefit from these new roles.

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6. Publicize Models of Success

Beyond extraordinary leadership, grassroots efforts, training, and funding, the widespread social changes needed to close the digital divide will require models of change that inspire action and destroy stereotypes. Impressive stories of Internet use by senior citizens, inner-city children, recent immigrants, and family farmers are already emerging. These stories show others how they, too, can become proficient computer users and how this technology can truly benefit everyone.

The media are vital in spreading these stories and keeping the digital divide on the national agenda. In 2000, PBS's *The Digital Divide* documentary presented several success stories.[13] The George Lucas Educational Foundation is developing a multimedia project on teachers and technology titled "Teaching in the Digital Age." The project provides Web content, documentary films, a resource book, and newsletters chronicling exemplary teachers using technology, often in underserved schools.[14]

These success stories deliver inspiration, captured from the perspiration of leading individuals and groups, and publicize models for others to adapt. In the national effort to cross the digital divide, today's pathfinders are charting a road map for others to follow.

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1. Moore's Law (from Intel cofounder Gordon Moore) states that computer power doubles every 18 months. Thus, computers are becoming obsolete within three cycles of Moore's Law.

2. Paisley, W. Children, new media, and microcomputers. In *Children and microcomputers: Research on the newest medium.* M. Chen and W. Paisley, eds. Beverly Hills, CA: Sage Publications, 1985.

3. As one example, a national campaign called "PowerUP" provides technology and training for lower-income communities. The campaign, announced in 1999, is headed by Steve Case, AOL Time Warner chair, and General Colin Powell. For more information, see the PowerUP Web site at http://www.powerup.org.

4. Declines in cost will continue to accompany the increased computer power described by Moore's law and push the PC on its way to becoming a commonplace digital appliance. In early 2000, Ford and Delta Airlines offered new PCs and unlimited Internet access to their employees at costs from $5 to $12 per month. See Hamilton, D.P., and Brannigan, M. Fledgling PeoplePC lands deal with Ford and Delta—supply agreements show hope for struggling "nearly free" PC market. *Wall Street Journal.* February 7, 2000, at B4.

5. *The E-rate in America: A tale of four cities.* Washington, DC: The Benton Foundation, February 2000.

6. See the U.S. Department of Education Web site at http://www.ed.gov/Technology/ digdiv.html.

7. The Children's Partnership. *Internet content for low-income users.* Washington, DC: The Children's Partnership, March 2000.

8. Behrmann, M. Assistive technology for young children in special education. In *ASCD yearbook 1998: Learning with technology.* C. Dede, ed. Alexandria, VA: Association for Supervision and Curriculum Development, 1998, pp. 73–93.

9. See the Center for Applied Special Technology (CAST) Web site at http://www.cast.org.

10. Palmer, E. *Television and America's children: A crisis of neglect.* New York: Oxford University Press, 1988.

11. Lesser, G.S. *Children and television: Lessons from Sesame Street.* New York: Random House, 1974; see also Gibbon, S.Y., Palmer, E.L., and Fowles, B.M. Sesame Street, The Electric Company, and reading. In *Towards a literate society.* J. Carroll and J. Chall, eds. New York: McGraw-Hill, 1975.

12. See the Generation Why Web site at http://genwhy.wednet.edu.

13. See the Digital Divide Web site at http://www.pbs.org/digitaldivide.

14. See the George Lucas Educational Foundation Web site at http://glef.org. The newsletter, *Edutopia,* which addresses the themes of "Bridging the Digital Divide" and "Teaching in the Digital Age," is also available on the Web site.

2 COMMENTARY

Jane M. Healy

Jane M. Healy, Ph.D., is an educational psychologist, author, consultant, and lecturer in Vail, CO.

The question posed for consideration presupposes that it is possible to ensure desirable outcomes for children within the "digital landscape." As is clear from the articles in this journal issue, however, such a rosy future is far from certain. The articles highlight both the extraordinary promise of educational computing and the major tensions threatening to derail it. Two of these conflicts will be briefly addressed here, and then some pressing questions will be raised—questions that have barely been considered in America's frantic rush to plug children into machines.

Conflict #1: Children as Learners versus Children as Consumers

Several articles in this journal issue suggest that computer use may be either constructive or destructive, depending on whether applications have important content with well-designed programming features and whether thoughtful, skilled adults supervise use of the applications. Montgomery's article warns that young people's intellects and value systems are under serious assault by Internet marketers. In addition, much of the commercial software advertised as "edutainment" has little or no base in educational research and may consist of superficial drills, games, or "mind candy" spun by programmers untrained in learning theory who operate under pressure to bring a glitzy product quickly to market.[1] As Becker points out, a great deal of unsupervised computer use is recreational, characterized in other studies as "game playing," "chatting," "random Internet surfing,"[2] or "trial and error button clicking to 'win' or gain a superficial reward" (such as an amusing graphic or game).[3] Researchers are exploring how applications can be designed to provide a base for developing students' reflective and systematic problem-solving skills or for building personal motivation for more difficult tasks, rather than simply to provide "fun,"[4] but the task of developing and field-testing good applications is expensive and unlikely to yield a quick payoff in a market-driven system.

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The term *equity* frequently is appropriated by industry officials who perceive a commercial bonanza in the funding of technology for disadvantaged school districts; however, so-called "disadvantaged" students (without computers but with excellent teachers and curricula) are far better off than children who spend time on mindless or rote-level technology without substantive, interpersonal learning experiences. Connection to the Internet is an expensive distraction when the user lacks the skills to read the screens or the critical reasoning to evaluate and prioritize data. Those who believe that an Internet connection will solve the problems of inadequate schools should be reminded of the popular acronym used in business: "DINK" (Data Is Not Knowledge). Connectivity is a dubious goal without fundamental school reform.

Conflict #2: The Ideal versus the Real

The rush into educational computing has siphoned off billions of dollars in scarce educational resources, taking funds needed elsewhere. For example, in an earlier issue of this journal, it was estimated that programs to meet the needs of all preschool children in the United States would cost between $50 billion and $80 billion[5]—the same amount projected (that actually was an underestimate) for linking every child in the United States to the Internet.[6] Throughout the country, schools are cutting art and music programs to install computer labs, and teachers in schools with elaborate technology often report inadequate staffing of guidance counselors or reading specialists.

Despite the promising developments reported in this journal issue, summative research has not yet demonstrated significant student gains to justify technology expense,

especially for younger students.[7] (The one exception is assistive technology for students with disabilities, summarized in this journal issue by Hasselbring and Williams Glaser.) The gap between possible and actual outcomes resulting from children's use of computers is largely due to the fact that what happens in research trials is not what happens when programs are implemented in most classrooms—or family rooms. As made clear in the article by Roschelle and colleagues in this journal issue, the learning and prosocial gains of students whose excellent teachers work closely with researchers under near-optimum conditions—including ongoing technical support—are difficult to replicate in the typical crowded, understaffed classroom, where teachers may lack support and even fail to share or understand the designer's learning goals. Likewise, much of home computing's educational value is lost without parental supervision and support, at least for younger children. For this reason, professionals should consider advising parents to keep children's computers in a central location where use can be monitored until their children have sufficient maturity to make sensible choices about their use of technology.

Critical Questions

Computer technology will eventually prove its worth only if education comes before entertainment, and if knowledgeable professionals are supported in developing research-based paradigms that work in actual practice. Several difficult questions must also be addressed if this technology is to benefit, rather than harm, children.

How does computer use affect children's physical health?

Although significant health risks of extensive computer use are documented for adults,[8] virtually no research has addressed this issue for children. Potential risks include eyestrain and changes in vision; musculoskeletal problems, including repetitive stress injuries such as carpal tunnel syndrome; and potential effects from electromagnetic radiation emissions, particularly with exposure from less than three feet or from the backs and sides of older machines. Despite such potential effects, school computer labs and classrooms reveal an almost universal ignorance or disregard of safety standards mandated in the adult workplace.[9]

Recreational use poses additional physical hazards. As discussed in the article by Subrahmanyam and colleagues in this journal issue, a few children with undiagnosed photosensitive epilepsy have experienced seizures while playing certain video games. This condition is still poorly understood and is thought to be rare, but may be more common than generally recognized.[10] In addition, increased "screen time" may deprive children of all the physical, social, and cognitive learning concomitant with active, unstructured play. Because commercial computer applications are designed to be so visually and behaviorally engrossing, teachers and parents report that computer use is one of the few activities that can subvert youngsters' natural instincts for physical and social exercise.

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As even very young children spend increasing amounts of time at computer terminals—inadequately supervised and often with furniture inappropriately sized and placed—these questions must be addressed. Health professionals in particular should be alert for problems related to frequent computer use and should demand more adequate research.

What are the cognitive and social-emotional effects of technology on the growing brain?

Before attaching its young for long periods to an experimental machine, a prudent society might also inquire about its potential long-term effects on the brain. The article by Subrahmanyam and colleagues in this journal issue provides clear evidence that computers are changing both the way children spend their time and the mental habits and skills of today's "clickerati."[11] The plasticity of the human cortex in response to varying types of environmental stimuli has long been recognized, along with growth cycles (or "sensitive" periods), as critical in the development of sensory and cognitive skills.[12] Little research has addressed the neurological effects of extended exposure to highly engrossing electronic stimuli, however. Can the functional and structural aspects of the brain subtly be shifted by significant changes in the way youngsters spend their time? Could children's mental habits, such as internally generated motivation, attention, oral expression, listening skill, imagination, visual and verbal imagery, inner speech, or sequential analysis be affected by having their brains externally engaged by more holistic, fast-paced visual "games" in which language use is frequently absent? And would this development be positive or negative?

There is little, if any, evidence that the visual-spatial skills fostered by computer games have any specific transfer value to academic skills. Because a variety of discrete subskills comprise visual-spatial abilities, it will be increasingly important to establish which ones actually help children master math and science. It will also be important, however, to determine how much these activities erode verbal skills, which are still so fundamental for school success. Many questions about the effects of computer use on a child's developing brain demand better research and adult discretion in choosing digital playmates.

What are the developmental issues surrounding computer use for children?

A major unasked question concerns how computers can be most effectively used—or not

used—during periods of child and teen development. It is generally recognized that what is good for 15-year-olds may be damaging for 5-year-olds. Three years of investigation and observation have convinced this author, originally a staunch advocate of "the younger the better," that normally developing children under age seven are better off without computers.[13] In fact, recent research indicates that resources are more effectively deployed in middle and high school. In 1998, the first large-scale study of math gains from targeted computer use found eighth graders benefitting significantly more than fourth graders. Moreover, applications directed at the higher-order thinking skills, especially critical for older students, were most effective, whereas drill-and-practice programs and too much computer time overall proved counterproductive.[14]

Although the computer industry has engaged in an unprecedented campaign to convince parents that their youngsters will fall behind if they do not learn computing in preschool, no evidence supports this claim. Equipment and the definition of "computer skills" are changing rapidly and can evidently be mastered even into adulthood. Little substantive research has looked at very early computer use, but one study showing some positive gains also suggested that use of a popular reading "readiness" software program significantly reduced preschoolers' scores on a standard test of creativity.[15] Clearly, this is a complex issue, but the mere fact that computers can steal time from hands-on, three-dimensional, imaginative, social, and language-rich playtime should inspire caution.

What unique role can computers play in education?

Rather than using new technologies to recapitulate methods and subject matter of traditional pedagogy (such as using "electronic workbooks" for word processing), educators must ask, "What can this technology do that we can't do as well or better with a less costly or better proven method?" Online simulations for middle schoolers, for example, or innovative practices for older students in math and science stand to make schooling more dynamic, engaging, and effective—but only if educational policymakers can resist commercial expediency and public pressure and proceed deliberately and creatively to rethink basic concepts of "schooling."

The Future of "Wired" Childhood

Direct marketing to children—plus a campaign to "prepare them for the future" with depersonalized and reductive technologies—are new features to the landscape of childhood. They beg the question of how infatuation with a virtual culture may devalue basic human needs. An overwhelming body of research demonstrates that close human contact is the most essential ingredient in becoming an effective human being. Which is more important—our youngsters' humanity or their marketability? Will children thrive on glitz or on substance? Can parents and educators gather patience for the slow and laborious process by which a child creates a self? Children's futures—and ours—depend on the answers.

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3. Healy, J.M. *Failure to connect: How computers affect our children's minds and what we can do about it.* New York: Simon & Schuster/Touchstone, 1999.

4. Cordova, D.I., and Lepper, M.R. Intrinsic motivation and the process of learning. *Journal of Educational Psychology* (1996) 88:715–30.

5. Gomby, D.S., Krantzler, N., Larner, M.B., et al. Financing child care: Analysis and recommendations. *The Future of Children* (1996) 6,2:5–25.

6. *USA Weekend.* February 14–16, 1997, p. 10.

7. See note no. 3, Healy.

8. Publications on video display terminals (revised) from the National Institute of Occupational Safety and Health. Cincinnati: Public Health Service, U.S. Department of Health and Human Services, June 1991.

9. See note no. 3, Healy.

10. Graf, W.D., Chatrian, G., Glass, S.T., and Knauss, T.A. Video game-related seizures. *Pediatrics* (1994) 93:554.

11. The term *clickerati* was coined by Idit Harel, CEO and founder of MaMaMedia, Inc. See, for example, the Idit Harel interview on Women.com, December 15, 1999, available online at http://www.women.net/tech/spotlight/harelTrans.html.

12. See, for example, Fischer, K.W., and Rose, S.P. Dynamic growth cycles of brain and cognitive development. In *Developmental neuroimaging: Mapping the development of brain and behavior.* R. Thatcher, G.R. Lyon, J. Rumsey, and N. Krasnegor, eds. New York: Academic Press, 1996; see also Diamond, M., and Hobson, J. *Magic trees of the mind.* New York: Dutton, 1998.

13. For a full explanation, see note no. 3, Healy, chapter 7.

14. Wenglinsky, H. *Does it compute? The relationship between educational technology and student achievement in mathematics.* Princeton, NJ: Educational Testing Service, 1998.

15. Haughland, S.W. The effect of computer software on preschool children's developmental gains. *Journal of Computing in Childhood Education* (1992) 3:15–30.

3 COMMENTARY

Mitchel J. Resnick

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Let's start with a quiz. Which of these three does not belong: computers, television, finger paint? There is no correct answer to

this question, but how you answer the question says a lot about how you think about computers.

For most people, the answer seems obvious: "finger paint" doesn't fit. After all, computers and televisions were both invented in the twentieth century, both involve electronic technology, both can deliver information to large numbers of people. None of that is true for finger paint.

But, in my mind, computers will not live up to their full potential until we start to think of them more like finger paint and less like television. With finger paint, unlike television, people can create their own pictures. Computers can be used in a similar way. In addition to accessing Web pages, people can create their own Web pages. In addition to downloading MP3 music files, people can create their own music compositions. In addition to playing SimCity, people can create their own simulated worlds.

These types of activities are especially important in the lives of children. Research has shown that many of children's best learning experiences come when they are engaged in designing and creating things, especially things that are meaningful to themselves or others around them.[1] When children create pictures with finger paint, they have a chance to learn how colors mix together. When they build houses and castles with building blocks, they have a chance to learn about structures and stability. When they make bracelets with colored beads, they have a chance to learn about symmetries and patterns.

Computers, like finger paint, blocks, and beads, can be used as a "material" for making things. Compared with traditional materials, computers expand the range of things that children can create—and the range of concepts that they can learn while creating.[2] But in most places today, computers aren't used in this way. As discussed in the articles by Becker and by Subrahmanyam and colleagues in this journal issue, children most often use computers for playing games or accessing information on the Web. Only rarely do they use computers to create, to design, or to invent.

What can we do to change this? As Roschelle and colleagues discuss in their article in this journal issue, change is especially difficult in schools because sustainable change can occur only if many things change at the same time: curricula, methods of assessment, teacher development, school structure. Perhaps the biggest challenge is changing people's ways of thinking about learning and education. Too many people view education as a process of transmitting information from teacher to learner, rather than as a process in which learners actively build an understanding of the world based on their experiences and interactions. So when people think about educational uses of computers, they too often look for new ways to transmit information—rather than for new ways for children to create, experiment, and explore.

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Part of the problem is the nature of computers themselves. The computers in widespread use today were designed for and by the television generation. They even look like televisions. Is it any surprise that computers are so rarely used for finger paint–style applications?

Today's children deserve better. We live in an unprecedented era in which children are often more competent and confident with new media than their parents are. This type of reversal hasn't happened before. When the printing press was invented, children were not among the leading-edge users as they are with today's computers. Alan Kay, one of the fathers of the personal computer, observes that the term "technology" is used to refer to anything that wasn't invented before you were born.[3] Thus, computers aren't a technology for today's children, they are simply part of the everyday landscape.

An important challenge for the future is to develop a new generation of computer technologies worthy of this new generation of children. Ideally, these new technologies should provide children with "design leverage," enabling them to create things that would have been difficult for them to create in the past. In addition, the new technologies should provide children with "conceptual leverage," enabling them to learn concepts that would have been difficult for them to learn in the past.

These new technologies might look very different from traditional computers. For example, my research group at the MIT Media Laboratory has developed a family of "programmable bricks": tiny computers embedded inside children's building blocks.[4] With these bricks, children can build computational power directly into their physical-world constructions, blurring the boundaries between the physical and digital worlds (and hopefully getting the best of both worlds). In pilot studies, children have used programmable bricks to build a variety of creative constructions, including an odometer for roller blades (using a magnetic sensor to count wheel rotations), a diary security system (using a touch sensor to detect if anyone tried to open the diary), and an automated hamster cage (using a light sensor to monitor the hamster's movements during the day).

One 11-year-old girl, named Jenny, was interested in birds, and she decided to use programmable bricks to build a new type of bird feeder. She started by making a wooden lever that served as a perch for the birds. When a bird landed, it would trigger a touch sensor, sending a signal to a programmable brick, which turned on a Lego mechanism, which then pushed down the shutter of a camera, taking a picture of the bird.

The design-oriented nature of the project was clearly important for Jenny. As she described it, "The fun part is knowing that *you* made it; *my* machine can take pictures of

birds." At the same time, the project served as a rich context for engaging in scientific inquiry and learning science-related concepts. Jenny developed a deeper understanding of some concepts (such as mechanical advantage) she had previously studied in school, but had never really appreciated. And she began to work with some engineering concepts (related to feedback and control) that traditionally have been taught only at the university level.[5]

How can we help more children have experiences similar to Jenny's? As discussed in the article by Becker in this journal issue, lack of access to technology is one obstacle. Children in certain socioeconomic groups have far less access to technology than others. Although this "access gap" is an important societal problem today, it will not be the primary bottleneck in the future. The cost of computational power will continue to drop during the next several years, making access less of a problem. The real problem is not the "access gap," but the "fluency gap."[6,7] Even if all children have access to technology, will they, like Jenny, become "fluent" with the new technology, using it to explore, create, and invent? Or will they simply download videos and music from the Web? In short, will they use computers like finger paint or like television?

Helping all children become truly fluent with computer technologies will require new types of technology, new educational strategies, and new public policies—and a new public understanding of the nature of learning. It won't be easy. But it's the only way that computers will have a deep and lasting impact on the lives of children.

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2. Resnick, M. Technologies for lifelong kindergarten. *Educational Technology Research and Development* (1998) 46:43–55.

3. As one of the founders of the Xerox Palo Alto Research Center during the 1960s and 1970s, Dr. Alan Kay led one of several groups that worked to develop the ideas behind modern computing, including the laptop computer, the overlapping-window interface, and object-oriented programming. Dr. Kay's professional experience also included stints as a professor at the Stanford Artificial Intelligence Laboratory, chief scientist at Atari, and a fellow at Apple Computer. He is currently a fellow and vice president of research and development at The Walt Disney Company.

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5. Resnick, M., Berg, R., and Eisenberg, M. Beyond black boxes: Bringing transparency and aesthetics back to scientific investigation. *Journal of the Learning Sciences* (2000) 9:7–30.

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4 COMMENTARY

Laurie A. Lipper
Wendy Lazarus

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As the digital age progresses at an unprecedented rate, parents are uniquely positioned to help ensure that computer technology is used equitably, effectively, and ethically to promote positive child development. Because of their relationship and proximity to young people, parents can and should play a pivotal role in guiding new media use within the family and school, and in advocating in the public policy arena and the marketplace for the development of technology in ways that are beneficial to children.

As discussed in the article by Becker in this journal issue, nearly one in four children in the United States was accessing the Internet on home computers in 1998.[1] More recent survey data indicate that the number of children, especially younger children, going online is growing steadily. As of December 1999, more children ages 12 and under were using the Internet (13.2 million) than were children ages 13 to 18 (12.5 million).[2] Parents of these children are on the front line of the digital age. Through their own experiences and through the news media, they are coming to understand the issues, from privacy and commercialism to the need for quality content and safety.

In the most fundamental way, parents and other direct caregivers—such as grandparents, other family members, and child care workers—are able to teach their children safety rules, set appropriate limits for a child based on age and disposition, and tailor strategies to ensure that a child benefits from time spent with new media in the home.

Parents are in a position to connect their children's schoolwork with home use of computers and to advocate for sound technology policies at school. Studies consistently show that children benefit, and educational achievement increases, when parents are involved in their children's schoolwork. For children whose families lack home computers, motivated parents can play a crucial role in ensuring access to useful software and Internet content through schools, libraries, or community centers as various programs increase the new media resources in these settings (see Appendix A). Moreover, in instances where young people are experiencing educational, emotional, or social problems in relation to computers and the Internet, parents—with proper information—are best suited to identify those troubles and advocate for appropriate help.

Beyond the direct impact they exert within the family, parents can be a powerful voice for children as the digital society develops; however, the needs, concerns, and wishes of parents have barely been heard in the public debate as new Internet uses and products are developed. Parents have not been given the information and tools they want for their own children, and their desires for quality educational media have not yet taken hold. Nor have the needs of subsets of parents, such as low-income, minority, and rural parents, been adequately addressed and incorporated into the development of the digital society.

What Do We Know About Parents' Views?

As discussed in several articles in this journal issue, to many parents, the new technologies of the information age represent both the promise of vast benefits and the potential for harm to their children. These mixed sentiments often manifest themselves in the opinions of parents who simultaneously applaud the positive uses of the Internet while fearing the negative aspects and searching for ways to control or monitor more closely the online experiences of their children.

In fact, according to a 1999 study about media influences, nearly 20% of parents rate the Internet as their chief concern in raising their children.[3] In general, however, studies reflect parents' ambivalence about new media. For example, in a study of parental and press reactions to child safety on the Internet, also conducted in 1999, three-quarters of American parents reported that they believe that the Internet is a positive learning tool, but also cited access to pornography or the potential for their children's disclosure of personal information as their top fears about the nefarious aspects of the online world.[4] This study also found that parents' ambivalence about the Internet is reinforced by the press coverage about the subject.

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Findings from another recent study detailing the views of parents about the technological revolution and its effects on child rearing also are instructive.[5] Parents reported being aware that new media can be sinister in its effects and marketing strategies, and believed that much of the Internet is overcommercialized. Most parents acknowledged and embraced their responsibility for monitoring their children's time in the digital world, but expressed concern about the knowledge and time required to accomplish this task. Many said they felt ill-equipped to be effective caretakers of their children online, and expressed a palpable sense of urgency and need for greater resources to help them guide their children through an often confusing, stimulus-rich world of technology and the Internet.

The online world apparently is challenging for all parents, but low-income parents in particular noted several additional obstacles to keeping their children safe while allowing their children to reap the positive and educational benefits of new media. For example, many expressed worries that the lack of a home computer may put their children at a disadvantage in completing homework, presenting schoolwork, and preparing for high-tech careers. Because they were much less likely to have Internet access at home, low-income parents also felt less familiar with the forces their children are exposed to through schools, libraries, or other technology access points. In addition, even with home access, low-income parents are likely to have lower levels of technological literacy, making it more difficult for them to understand what their children are seeing and experiencing online. Perhaps partly as a result of a limited ability to monitor their children themselves, low- and moderate-income parents generally expressed higher expectations of Internet service providers to filter content and watch out for their children's safety. In contrast, upper-income parents thought that the providers have some responsibility but felt more confident in shouldering more of this burden themselves.

In addition, low-income and minority adults reported, in a study released in March 2000, that current Internet content does not meet their needs and desires.[6] They expressed interest in practical information focused on the community, in content targeting those without high literacy levels or English-language skills, and in cultural information. The corresponding online analysis revealed that all of these areas are lacking in Internet content. Thus, as many as 50 million Americans are underserved by what is currently on the Web.

As efforts move forward to involve parents in the online world, special efforts must be made to engage low-income parents through churches, Head Start programs, and other organizations they trust. Also, materials and activities must be developed specifically for the reading level and language needs of these parents.

Building on a Long Tradition of Parent Advocacy

Many examples demonstrate what parents can achieve when organized to advance their children's best interests. For instance, mothers who organized across the country in the early 1900s sparked the creation of government initiatives to protect children and families. These included the establishment of the Children's Bureau as a federal agency and the enactment of laws in many states establishing compulsory schooling, protective labor practices for women, and mothers' pensions. In the case of media, parent advocates have played an active role in lobbying for improved children's programming in film, radio, and television throughout the twentieth century, as chronicled in the article by Wartella and Jennings in this journal issue. Parent groups such as "Action for Children's Television" have helped raise awareness of, and secure limits on, advertising directed at children, and have worked to institutionalize and promote positive educational programming for children. Parents also have spurred the development of children's media through the Public Broadcasting System and have propelled a major market for quality educational software. Such efforts provide the foundation for parents to increase their involvement in online media and use their influence on the industry to create more quality content for children.

A variety of initiatives supporting parents are helping move in this direction. Across the country, initiatives based in churches, schools, libraries, and community centers are aimed at increasing the technological literacy and comfort of parents and families with new media. Such initiatives offer a model for activating other communities around greater parental involvement in the technological lives of their children.[7] For example, a pilot, Parent Involvement Initiative, was launched in 1998 by four community-based organizations within a larger network of community centers offering technology skills training and open access time to California communities with historically low rates of technology access.[8] This initiative is designed to increase parent participation in the computer-based activities of their children, as well as increase parents' technological fluency and skill development. Positive results from this program are beginning to emerge.[9]

In addition, several organizations now provide resources for parents and policymakers online. The Children's Partnership, for example, provides a Web site that aggregates information about the best available noncommercial sites and online resources about children and the Internet. Such resources include *The Parents' Guide to the Information Superhighway*, which provides a step-by-step guide to help parents embarking on the path to greater technological fluency, and *The Parents' Online Resource Center*, which offers parents more than 100 links to quality, noncommercial sites ranging from homework help for children to job resources for parents—including useful Spanish-language links.[10]

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Where Do We Go from Here?

Content developers, Internet service providers, policymakers, and other major players involved in the technology industry all have a role to play in equipping parents to be the good guides they want to be in the digital age. The modest steps that have been taken to provide practical information for parents must be expanded and reinforced. Just as our nation rallied to educate parents about the value of reading, the importance of the first three years in a child's development, safety rules regarding seat belts, and the dangers of drugs and alcohol, so we must now use every creative means to reach out to parents with practical information about navigating the digital age with their children.

To accomplish this goal, the following actions are needed:

Solicit parents' views regularly and frequently, and consider them in the development of public policies and private-sector products. Parents have an important voice to add to the debate over the best and safest uses of new media for their children.

Strengthen and spread the promising parent involvement programs being tried across the country to reach many more parents, especially those in low-income communities.

Address the unique needs of low-income parents who have lower access rates, lower technology literacy rates, and fewer workplace incentives to support technology skills for their children.

Build a research base by aggregating the research that exists about children and new media for use by policymakers, industry leaders, and opinion leaders. Commission research in areas where not enough is known, and make findings available in a readily accessible and readable format for decision makers.

Brief creators and producers of media about child development needs and concerns so the way they market and structure their products will be sensitive to children's positive development. Use the power of a concerted parents' movement to demand changes in the ways the industry affects our children.

At this crucial stage in the development of computer technology, parent involvement is essential to secure what is best for young people in a digital age. History demonstrates that media are developed in ways that are beneficial to children only when there is vigorous

and sustained pressure from parents. We must support parents' vital role in shaping the evolution of more quality content in the new media that will surround our children for many years to come.

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1. See also Cyber Dialogue/FIND/SVP. *1998 American Internet user survey.* September 1998.

2. Cyber Dialogue. Interactive consumers. *The Internet Consumer.* December 1999.

3. Stanger, J.D., and Gridina, N. *Media in the home 1999: The fourth annual survey of parents and children.* Philadelphia: Annenberg Public Policy Center, University of Pennsylvania, June 28, 1999.

4. Turow, J. *The Internet and the family: The view from the parents, the view from the press.* Philadelphia: Annenberg Public Policy Center, University of Pennsylvania, May 1999.

5. *Understanding the views of parents in a digital world.* Public opinion research conducted by Lake, Snell, Perry and Associates for The Children's Partnership and The Markle Foundation, 1999.

6. The Children's Partnership. *Online content for low-income and underserved Americans: The digital divide's new frontier.* Santa Monica, CA: The Children's Partnership, March 2000.

7. The Children's Partnership has researched, reviewed, and disseminated information about many of these "Promising Parent Programs." Summaries and contact information are available at http://www.childrenspartnership.org.

8. This network of 11 community centers, Computers In Our Future, began in 1995 with a grant from The California Wellness Foundation in partnership with Pacific Bell, AT&T, Microsoft Corporation, Computers for Kids, FutureNet, The Mattel Foundation, Adobe Systems Inc., and O'Melveny and Myers. Nearly 16,000 community residents used these centers in the program's first two years. For more information, see the Computers In Our Future Web site at http://www.compfuture.org.

9. For the latest information about the Parent Involvement Initiative, see the Computers in Our Future Web site at http://www.compfuture.org.

10. See The Children's Partnership Web site at http://www.childrenspartnership.org.

5 COMMENTARY

Chris J. Dede

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Developed countries are shifting from loosely coupled, mature industrial economies to an interwoven, knowledge-based global marketplace.[1] Driven by advances in information technology, this economic evolution is the largest leap from yesterday's workplace to tomorrow's since the beginning of the industrial revolution.[2] In response, we must reshape children's learning experiences in and out of school to prepare them for a future quite different from the immediate past.[3] Meeting this challenge involves teaching new skills, not simply teaching old skills better. Aiding more students to reach a higher standard of achievement in today's curriculum—such as having all pupils take more advanced math courses, or raising everyone's scores on standardized tests—is desirable, but such improvements in traditional educational outcomes are not enough to prepare pupils for twenty-first century civilization.[4] Children also need to master higher-order cognitive, affective, and social skills that are not central to mature industrial societies, but are vital in a knowledge-based economy.[5] Such skills include the ability to "thrive on chaos" (make rapid decisions based on incomplete information to resolve novel situations); to collaborate with a diverse team—face-to-face or across a distance—to accomplish a task; and to filter through a sea of quasi-accurate information to create, and share knowledge.[6] All students, not just the students who are "gifted and talented," need to master these capabilities. Sustaining prosperity and justice in a knowledge-based economy governed by democratic political methods requires that all citizens in our society be adept in such higher-order skills.

Just as information technology has enhanced effectiveness in medicine, finance, manufacturing, and numerous other sectors of society, advanced computing and telecommunications have the potential to help children master the complex capabilities needed for the twenty-first century.[7] However, technology is not a "vitamin" whose mere presence in schools and homes catalyzes better educational outcomes. Nor are new media just another subject in the curriculum, suited primarily for inculcating technical literacy with the business applications children may encounter as adults. Instead, emerging interactive media are tools that can help provide rich curricula, powerful pedagogies, and effective organizational structures; empower disenfranchised learners; and create strong links among schools, homes, workplaces, and communities.[8] But fully realizing this technological vision requires a complex implementation process. As discussed in the articles by Becker and by Roschelle and colleagues in this journal issue, successful incorporation of technology into the classroom involves sustained, large-scale, simultaneous innovations in schools' curricula, pedagogy, assessment, professional development, administration, and

organizational structures. Strategies for equity across the larger society require partnerships for learning among schools, businesses, homes, and neighborhoods.[9]

What shifts in current policies and practices are necessary to accomplish this vision? Three immediate initiatives are vital: increase resources to educational research; provide access and content to meet the needs of all children; and increase investment in developing the creation of more technology-rich learning environments.

1. Increase resources for educational research.

The federal government and private foundations should allocate increased resources to educational research to assess the strengths and limits of emerging learning technologies and to develop effective strategies for their implementation. Such resources are needed to help ensure that the substantial new money now being expended on creating a technology infrastructure for schools is being spent wisely.

Compared to other sectors of society, little is spent on research in education; and, as a result, many opportunities for improvement are unrealized. A comparison between the American pharmaceutical industry and the American education system helps illustrate this point. In 1995, the United States spent about $70 billion on prescription and non-prescription medications and invested about 23% of this amount on drug development and testing. In contrast, in 1995 our nation spent about $300 billion on public K–12 education, but invested less than 0.1% of that amount to determine what educational techniques actually work and to find ways to improve them.[10] In 1997, the President's Council of Advisors in Science and Technology (PCAST) cited this situation to help support its recommendation for $1.5 billion in new spending on research focusing on learning technologies.

Thus far, however, no significant funding increases for education research on use of technology have occurred. The PCAST report was followed by much rhetoric from politicians and corporate executives, but funding changes have consisted largely of a cosmetic shift of $30 million in existing educational research funds. This is wholly inadequate. Thirty percent of technology expenditures should go to professional development to ensure that computers and telecommunications are used well. Another 10% of federal and state total investments in learning technologies should be directed to educational research and dissemination, with emphases on sophisticated curriculum development; coordination of research activities among states, federal agencies, and private foundations; and implementation studies developed jointly by scholars, practitioners, and policymakers. A crucial priority in this endeavor should be to share information and build the capacity of the educational research community with the skills and knowledge of practitioners. Blueprints for making increased expenditures are available in the 1997 PCAST report; the issue is moving beyond rhetoric to action.

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2. Provide access and content for all children.

To realize the full power of sophisticated computers and telecommunications, federal and state governments, private foundations, businesses, and citizens should provide increased support to equity initiatives that help children from all walks of life, including learners with disabilities. Throughout history, innovative information technologies at first widened inequities within civilization because initial access to the differential advantage they bring is restricted to the few people who can afford the substantial expense of the new technology.[11] As emerging media mature, drop in price, and are widely adopted, however, the ultimate effect of the new technology will be to make society more egalitarian. For example, the world of universal telephone service is a more equitable environment than was the world of messengers and telegraph offices. The challenge for current educational policy is to minimize the period during which the gap between the "haves" and "have nots" widens, moving rapidly to a maturity of usage and a universality of access that promotes increased equity.

Most of society's current attempts to decrease the widened inequalities new educational technologies could create are centered on access and literacy. To compensate for more home-based technology in affluent areas, many feel that our best strategy is providing teachers and students in low socioeconomic status areas with additional technology to "level the playing field."[12] Thus, in schools serving disadvantaged and at-risk populations, extra efforts are made to increase the amount of computers and communications available. Similarly, educators and learners in less-advantaged areas are given special training to ensure that they are literate in information tools, such as Web browsers.

The "access and literacy" approach to educational equity is a good place to begin, but is inadequate unless it also takes the next step to address issues of content and services. The online materials and types of assistance that learners and teachers can access must reflect the needs and interests of diverse and at-risk students. The real issue in technological equity is empowerment, which requires tailoring information technology to give dispossessed groups what they want. For example, information technology can improve public services through the use of community-based information terminals offering improved access to health care, welfare, education, and

other social services for immigrant and minority populations. Online communication tools can also help these groups increase their participation in voting and forming coalitions for political action. Support for uses to improve public services appears to be quite strong, but local elected officials have shown much less interest in applications that promote broader participation in the political process.

To truly achieve educational equity, it is vital to work collaboratively with "have-not" populations in developing online content and services tailored to their needs and designed to build on their strengths and respond to their agendas. An essential priority in accomplishing this goal involves broadening the present educational technology movement to include more substantial representation from minority groups and the disenfranchised. Currently, such groups see the initiatives of the movement as peripheral to their needs. But without the full participation of all groups in our diverse society, efforts to improve access and literacy will fall short of the goal of preparing all children for success. Involvement of all society in the development of educational technology is essential to achieving justice and prosperity in America in the twenty-first century.

3. Increase investments in developing technology-rich learning environments.

How a medium shapes its users, as well as its message, is a central issue. The telephone creates conversationalists; the book develops imaginers who can conjure rich mental images from sparse symbols on a printed page. Some television programs induce passive observers; other programs, such as *Sesame Street*, can spark viewers' enthusiasm and enrich their perspectives. Now, high-performance computing and communications technology has created new interactive media capable of great good or ill.

Several articles in this journal issue document the many exciting models for education and "edutainment" emerging in the research community, but such applications are being largely ignored in society. As Becker points out, few teachers are using classroom computers for the more sophisticated and creative uses of technology linked to the strongest advances in learning. And as discussed in the article by Montgomery in this journal issue, few of the most highly acclaimed Internet sites for children can be found on lists of sites that are viewed most often. Media corporations, driven by efforts to maximize profits and market share, tend to focus the bulk of their resources on producing entertainment fixated on violence and sensationalism, instead of developing "edutainment" that provides children with fantasy, fun, and mindful preparation for the twenty-first century.[13] Unless the content providers for new media can be challenged to create more quality content for children, and children can be persuaded to use the better software and log on to the higher-quality sites, today's "couch potatoes" vicariously living in the fantasy world of television may become tomorrow's "couch funguses" immersed as protagonists in shared "virtual environment soap operas."

We have the technical and economic capacity to develop technology-rich learning environments for children that prepare them for life as adults in a world very different from the one we have known. Whether we have the political and cultural will to accomplish innovative uses of media for learning and empowerment across all segments of society remains to be seen.

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