Rethinking Learning in the Digital Age

Mitchel Resnick

The Media Laboratory
Massachusetts Institute of Technology

First, the good news: in the years ahead, the declining cost of computation will make digital technologies accessible to nearly everyone in all parts of the world, from inner-city neighborhoods in the United States to rural villages in developing nations. These new technologies have the potential to fundamentally transform how and what people learn throughout their lives. Just as advances in biotechnologies made possible the "green revolution" in agriculture, new digital technologies make possible a "learning revolution" in education.

Now, the bad news: while new digital technologies make a learning revolution possible, they certainly do not guarantee it. Early results are not encouraging. In most places where new technologies are being used in education today, the technologies are used simply to reinforce outmoded approaches to learning. Even as scientific and technological advances are transforming agriculture, medicine, and industry, ideas about and approaches to teaching and learning remain largely unchanged.

To take full advantage of new technologies, we need to fundamentally rethink our approaches to learning and education— and our ideas of how new technologies can support them.

Beyond Information

When people think about education and learning, they often think about information. They ask questions like: What information is most important for people to know? What are the best ways to transmit that information from one person (a teacher) to another (a learner)? What are the best ways to represent and display information so that it is both understandable and learnable?

It's not surprising that people see a natural connection between computers and education. Computers enable people to transmit, access, represent, and manipulate information in many new ways. Because education is associated with information and computers are associated with information, the two seem to make a perfect marriage.

This focus on information, however, is limiting and distorting, both for the field of education and for computers. If we want to take full advantage of new computational technologies, and if we want to help people become better thinkers and learners, we need to move beyond these information-centric views of computing and learning.

Over the past fifty years, psychologists and educational researchers, building on the pioneering work of Jean Piaget, have come to understand that learning is not a simple matter of information transmission. Teachers cannot simply pour information into the heads of learners; rather, learning is an active process in which people construct new understandings of the world around them through active exploration, experimentation, discussion, and reflection. In short: people don't *get* ideas; they *make* them.

As for computers, they are more than simply information machines, despite the common use of the phrase "information technology" or "IT." Of course, computers are wonderful for transmitting and accessing information, but they are, more broadly, a new medium through which people can create and express. If we use computers simply to deliver information to students, we are missing the revolutionary potential of the new technology for transforming learning and education.

Consider the following three things: computers, television, finger paint. Which of the three doesn't belong? 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, and both can deliver information to large numbers of people. None of that is true for finger paint.

But until we start to think of computers more like finger paint and less like television, computers will not live up to their full potential. Like finger paint (and unlike television), computers can be used for designing and creating things. In addition to accessing Web pages, people can create their own Web pages. In addition to downloading MP3 music files, people can compose their own music. In addition to playing SimCity, people can create their own simulated worlds.

It is design activities such as these that offer the greatest new learning opportunities with computers. Research has shown that many of our best learning experiences come when we are engaged in designing and creating things, especially things that are meaningful either to us or others around us (e.g., Papert 1993). When children create pictures with finger paint, for example, they learn how colors mix together. When they build houses and castles with building blocks, they learn about structures and stability. When they make bracelets with colored beads, they learn about symmetries and patterns.

Like finger paint, blocks, and beads, computers can also be used as a "material" for making things—and not just by children, but by everyone. Indeed, the computer is the most extraordinary construction material ever invented, enabling people to create anything from music videos to scientific simulations to robotic creatures. Computers can be seen as a universal construction material, greatly expanding what people can create and what they can learn in the process (Resnick 1998).

Digital Fluency

Unfortunately, most people don't use computers that way today. When people are introduced to computers today, they are typically taught how to look up information on the Web, how to use a word processor, how to send e-mail. But they don't become *fluent* with the technology.

What does it mean to be digitally fluent? Consider the analogy with learning a foreign language. If someone learned a few phrases so that they could read menus in restaurants and ask for directions on the street, would you consider them fluent in the language? Certainly not. That type of phrase-book knowledge is equivalent to the way most people use computers today. Is such knowledge useful? Yes. But it is not fluency.

To be truly fluent in a foreign language, you must be able to articulate a complex idea or tell an engaging story; in other words, you must be able to "make things" with language. Analogously, being digitally fluent involves not only knowing how to use technological tools, but also knowing how to construct things of significance with those tools (Papert and Resnick 1995).

Fluency with language not only has great utilitarian value in everyday life but also has a catalytic effect on learning. When you learn to read and write, you are in a better position to learn many other things. So, too, with digital fluency. In the years ahead, digital fluency will become a prerequisite for obtaining jobs, participating meaningfully in society, and learning throughout a lifetime.

Today, discussions about the "digital divide" typically focus on differences in access to computers. That will change. As the costs of computing decline, people everywhere will gain better access to digital technologies. But there is a real risk that only a small handful will be able to use the technologies fluently. In short, the "access gap" will shrink, but a serious "fluency gap" could remain.

Computer Clubhouses

To provide more young people with the opportunity to become digitally fluent, the Massachusetts Institute of Technology (MIT) Media Lab and the Boston Museum of Science have established a network of learning centers in economically disadvantaged communities. At these centers, called Computer Clubhouses, young people become designers and creators with new digital technologies. Clubhouse members use leading-edge software to create their own artwork, animations, simulations, multimedia presentations, musical compositions, websites, and robotic constructions (Resnick et al. 1998).

The first Computer Clubhouse opened in 1993 in Boston, serving youth between the ages of ten and eighteen. Based on

the success of the initial Clubhouse, a dozen more communities opened Computer Clubhouses over the next six years. Then, in 2000, Intel announced that it would provide support to open an additional hundred Computer Clubhouses around the world over the ensuing five years. There are now Clubhouses in India, Ireland, Israel, Colombia, Germany, the Philippines, and the United States, with new Clubhouses planned for 2002 in China, Costa Rica, Mexico, South Africa, and Taiwan.
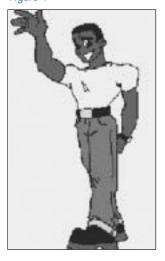
Computer Clubhouses are very different from most telecenters and community technology centers, which typically fall in one of two categories. Some technology centers merely provide access. People can do whatever they want: play games, surf the Web, use online chat rooms. Other centers offer structured courses teaching basic computer skills (such as keyboarding) and basic applications (such as word processing and spreadsheets).

Computer Clubhouses offer a third path, with different goals and a different approach. The aim is not simply to teach basic skills, but to help young people learn to express themselves and gain confidence in themselves as learners. If they are interested in video games, they don't come to the Clubhouse to play games; they come to create their own games. They don't download videos from the Web; they create their own videos. In the process, youth learn the heuristics of being a good designer: how to conceptualize a project, how to make use of the materials available, how to persist and find alternatives when things go wrong, how to collaborate with others, and how to view a project through the eyes of others. In short, they learn how to manage a complex project from start to finish.

The Computer Clubhouse approach strikes a balance between structure and freedom in the learning process. As Clubhouse youth work on projects based on their own interests, they receive a great deal of support from other members of the Clubhouse community (e.g., staff members, volunteer mentors, and other Clubhouse youth). There is a large collection of sample projects on the walls, shelves, and hard drives of the Clubhouses; these provide Clubhouse youth with a sense of the possible, and multiple entry points through which they can start. The goal is to provide enough freedom to enable Clubhouse youth to follow their fantasies, but also enough support to help them turn those fantasies into realities.

There is no doubt that the lives of many Computer Clubhouse members have been transformed by their time at the Clubhouses. Consider Mike Lee, who spent time at the original Computer Clubhouse in Boston. Mike first came to the Clubhouse after he had dropped out of high school. His true passion was drawing. He filled up notebook after notebook with sketches of cartoon characters. At the Clubhouse, Mike Lee developed a new method for his artwork. First, he would draw black-and-white sketches by hand. Then, he would scan the
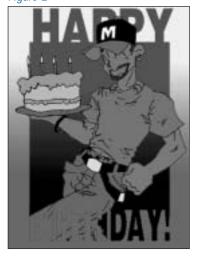
Figure 1

sketches into the computer and use the computer to color them in. His work often involved comic-book images of himself and his friends (Figure 1).

Over time, Mike learned to use more advanced computer techniques in his artwork (Figure 2). Everyone in the Clubhouse was impressed with Mike's creations, and other youth began to come to him for advice. Some members explicitly mimicked Mike's artistic style. Before long, a collection of "Mike Lee style" artwork filled the bulletin boards of the Clubhouse (Figure 3). "It's kind of flattering," says Mike.

For the first time in Mike's life, other people were looking up to him. He began to feel a new sense of responsibility. He decided to stop using guns in his artwork, feeling that it was a bad influence on the younger Clubhouse members. "My own personal artwork is more hard core, about street violence. I had a close friend who was shot and died," Mike explains. "But I don't want to bring that here. I have

Figure 2

an extra responsibility. Kids don't understand about guns; they think it's cool. They see a fight, it's natural they want to go see it. They don't understand. They're just kids."

Figure 3

Mike Lee began working with others at the Clubhouse on collaborative projects. Together, they created an online art gallery. Once a week, they met with a local artist who agreed to be a mentor for the project. After a year, their online art show was accepted as an exhibition at Siggraph, the world's premiere computer-graphics conference.

Figure 4

As Mike worked with others at the Clubhouse, he began to experiment with new artistic techniques. He added more computer effects, and he began working on digital collages combining photographs and graphics, while still maintaining his distinctive style (Figure 4). Over time, Mike explored how he might use his artwork as a form of social commentary and political expression (Figure 5).

As he worked at the Clubhouse, Mike Lee clearly learned a lot about computers and about graphic design. But he also began to develop his own ideas about teaching and learning. "At the Clubhouse, I was free to do what I wanted, learn what I wanted," says Mike. "Whatever I did was just for me. If I had taken computer courses [in school], there would have been all those assignments. Here I could be totally creative." Mike remembers—and appreciates—how the staff members treated him when he first started at the Clubhouse. They asked him to design the sign for the entrance to the Clubhouse, and looked to him as a resource. They never thought of him as a "high-school dropout" but as an artist.

Mike's artwork still has the same distinctive style, but he has become more fluent in expressing himself in computer-based media. Describing his current work, Mike talks about "dither nightmares" and "anti-aliasing problems"—ideas that would have been alien to him a few years ago. He says his artwork is "ten times better than last year."

Rethinking Technologies

In addition to rethinking our approaches to learning and education, we also need to rethink the technologies that we provide to young people.

Most of today's computers were designed primarily for use by adults in the workplace. We need to develop a new generation of computer technologies *worthy* of the next generation of children. It's not enough just to make computers faster; we need to develop new types of computers. Today's youth are ready and eager to do more with computers. We need to provide the hardware and software that will enable them to do so.

These new technologies might look very different from traditional computers. For example, my research group has developed a family of "programmable bricks": tiny computers embedded inside children's building blocks (Martin et al. 2000; Resnick et al. 1996). With these bricks, children can build computational power directly into their physical-world constructions, using the

Figure 5

programmable bricks to control motors, receive information from sensors, and even communicate with one another. The LEGO Company now sells a commercial version of these programmable bricks, under the name LEGO MindStorms.

Children have used our programmable bricks to build a variety of creative constructions, including an odometer for rollerblades (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).

One 11-year-old girl, named Jenny, was very 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 pushed down the shutter of a camera, taking a picture of the bird.

The design-oriented nature of the project was clearly very 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) that she had previously studied in school but had never really appreciated. She also began to work with some engineering concepts (related to feedback and control) that are traditionally taught only at the university level (Resnick et al. 2000).

Programmable bricks provided Jenny with "design leverage," enabling her to create things that would have been difficult for her to create in the past. At the same time, the bricks provided Jenny with "conceptual leverage," enabling her to learn concepts that would have been difficult for her to learn in the past.

Reforming Educational Reform

Increasingly, nations are recognizing that improving education is the best way to increase wealth, enhance health, and maintain peace. But there is little consensus on how to achieve an educated population, or even on what it means to have an educated population. Can progress towards an educated population be measured by counting the number of people in school? By the number of years they spend in school? By assessing their grades on standardized tests?

Every country in the world, it seems, has a plan for educational reform. But, in most cases, reform initiatives are superficial and incremental, and do not get at the heart of the problem. These initiatives often introduce new forms of testing and assessment, but leave in place (or make only small incremental changes to) existing curricula and existing teaching strategies. We need to reform educational reform.

Rethink how people learn. We need to fundamentally reorganize school classrooms. Instead of a centralized-control model (with a teacher delivering information to a roomful of students), we should take a more entrepreneurial approach to learning. Students can become more active and independent learners, with the teacher serving as consultant, not chief executive. Instead of dividing up the curriculum into separate disciplines (math, science, social studies, language), we should focus on themes and projects that cut across the disciplines, taking advantage of the rich connections among different domains of knowledge. Instead of dividing students according to age, we should encourage students of all ages to work together on projects, enabling them to learn from one another (and to learn by teaching one another). Instead of dividing the school day into hour-long slices, we should let students work on projects for extended periods of time, enabling them to follow through more deeply and meaningfully on the ideas that arise in the course of their work.

Rethink what people learn. Much of what children learn in schools today was designed for the era of paper-and-pencil. We need to update curricula for the digital age. One reason is obvious: Schools must prepare students with the new skills and ideas that are needed for living and working in a digital society. There is a second, subtler reason: new technologies are changing not only what students *should* learn, but also what they *can* learn. There are many ideas and topics that have always been important but were left out of traditional school curricula because they were too difficult to teach and learn with only paper, pencil, books, and blackboard. Some of these ideas are now accessible through creative use of new digital technologies. For example, children can now use computer simulations to explore the workings of systems in the world (everything from ecosystems to economic systems to immune systems) in ways that were previously not possible. Some ideas

that were previously introduced only at the university level can and should be learned much earlier. Finally, and perhaps most importantly, we need to transform curricula so that they focus less on "things to know" and more on "strategies for learning the things you don't know." As new technologies continue to quicken the pace of change in all parts of our lives, learning to become a better learner is far more important than learning to multiply fractions or memorizing the capitals of the world.

Rethink where and when people learn. Most education-reform initiatives appear to assume that learning takes place only between the ages of 6 and 18, between 8:00 A.M. and 3:00 P.M.—that is, when children are in schools. But schools are just part of a broader learning ecosystem. In the digital age, learning can and must become a daylong and lifelong experience. National education initiatives should aim to improve learning opportunities not only in schools, but also in homes, community centers, museums, and workplaces. In Denmark, for example, the Ministry of Education joined with the Ministry of Business and Industry to create Learning Lab Denmark, a new research lab that studies learning in all settings, in all stages of life. In the years ahead, the Internet will open up new learning opportunities, enabling new types of "knowledge-building communities" in which children (and adults) around the globe collaborate on projects and learn from one another.

Towards the Creative Society

In the 1980s, there was much talk about the transition from the "Industrial Society" to the "Information Society." No longer would natural resources and manufacturing be the driving forces in our economies and societies. Information was the new king.

In the 1990s, people began to talk about the "Knowledge Society." They began to realize that information itself would not bring about important change. Rather, the key was how people transformed information into knowledge and managed that knowledge.

The shift in focus from "information" to "knowledge" is an improvement. But I prefer a different conception: the "Creative Society." As I see it, success in the future will be based not on how much we know, but on our ability to think and act creatively.

The proliferation of digital technologies has accentuated the need for creative thinking in all aspects of our lives, and has also provided tools that can help us improve and reinvent ourselves. Throughout the world, computing and communications technologies are sparking a new entrepreneurial spirit, the creation of innovative products and services, and increased productivity. The importance of a well-educated, creative citizenry is greater than ever before.

Children should play a central role in this transition to the Creative Society. Childhood is one of the most creative periods of our lives. We must make sure that children's creativity is nourished and developed, and we must help children learn how to extend and refine their creative abilities, so that the creativity of childhood persists and grows throughout life.

To achieve these goals will require new approaches to education and learning, and new types of technologies to support those new approaches. The ultimate goal is a society of creative individuals who are constantly inventing new possibilities for themselves and their communities.

Acknowledgements

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