Failure to Connect

How Computers Affect Our Children's Minds—for Better and Worse

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Chapter Eight

Learning With Computers in Elementary, Middle, and High School

“>During our experiment we discovered that our hypothesis was
>unfortunately
>incorrect.”

Internet posting by middle-school students, Mott Hall School, Harlem, New York

“>Ah ha! You have done science!”

Response from scientist at Global Atmosphere Program, Environmental Defense Fund

Can technology contribute to learning? I think it can . . .

If a child has sufficient cognitive skills and social development

If technology is not substituting for important developmental experience

If we are not expecting it to do what it cannot do

If parenting and teaching retain priority

If the technology complements a well-planned curriculum

If it does not steal funds from more important needs (e.g., early childhood education, arts programs)

If we are judicious in planning and selection of software and activities

If we don't become seduced by flashy graphics and digital legerdemain

If parents and teachers are willing to provide a human “scaffold” for technology-assisted learning . . .

. . . then young people may profit from wise choices in this emerging field.

In this chapter I will try to show what it means to "scaffold" electronic learning for children of different ages. We will look at good examples of innovative computer use and at thorny but practical issues, such as whether, when, and how to teach students to write on a keyboard, how to use technology to teach basic skills, and how to assess student work in a new era of glossy cut-and-paste scholarship. Because telecommunications are such dramatic features in the electronic landscape, we will also take a serious look at some of their uses and misuses.

Anyone who is the least bit savvy about young people sees the enormous individual variations among kids at any age. For the purposes of discussion we will adopt some normative terms, but with the understanding that such generalizations have very fuzzy boundaries. For our purposes, "primary" will denote children of approximately five to seven years, "elementary" eight to ten, "middle school" eleven to thirteen, and "high school and beyond" fourteen and up.

My notes for this chapter include so much material that this topic should itself comprise a book. Therefore I apologize in advance for presenting only the barest outline of how digital teaching may prove to be a useful and appropriate assistant to mental development.

General Principles for Meaningful Technology Use

First, some general principles for educators and parents. If your child's school neglects these "basics," it may be wasting students' time and your money.

1. Fit the activity to the students' level of maturation and cognitive development.

2. Make the activity meaningful by linking it with students' interests and experiences.

3. Start with hands-on and interpersonal activities (e.g., practicing

building a classroom replica of the rain forest while participating in a simulated adventure in Central America).

4. Set clear outcomes and standards for learning. Help students evaluate when and how well these goals have been reached.

5. Ask for student self-reflection—preferably in writing—on work habits and process as well as on the outcome.

6. Plan for a meaningful and useful way for students to "show off" what they have learned (e.g., a multimedia demonstration about planets in the solar system; an explanatory guide to local historic spots; a virtual tour of Shakespeare's England; a musical performance incorporating original digital composition; an essay or letter to the editor expressing the student's point of view on a topic studied).

7. Don't be seduced by technical effects. Be sure technology use is always cloaked in understanding (e.g., require the child to explain the meaning of the data and to justify the formats chosen to present the project).

8. "Support" the organization and quality of long-term projects with clear written directions and expectations, checklists, and checkpoints for each step. Elementary-age children especially need adult supervision in planning and completing each step.

9. If students work in groups, make sure all share in total workload and various types of tasks (e.g., all have experience with designing graphics, and all must do some reading and writing). Acknowledge that some students are better at some types of tasks, and encourage all to enjoy exercising their talents as they also improve less-favored skills.

10. Encourage integration of understanding across modalities (e.g., prepare an original—written—script about something viewed; represent historical information in dance; draw illustrations for mathematical data in a spreadsheet; compare and contrast emotional response and learning from reading a book vs. seeing it in a video).

The Role of Parents and Teachers:

The best results from all technology use for children come accompanied by a skilled adult "coach" who adds language, empathy, and flexiher into the appropriate steps. One way to start cognitive coaching is to show a child how you accomplish something, describing your thinking process as you go. ("When I lay out this spreadsheet, I start by . . ." "See, I'm trying to remember to save my work periodically so I won't lose it.") An even better way, however (and more comfortable for most of us who are not computer experts ourselves), is to put the youngster in charge and learn with him. For example, sit with him, quietly commenting or suggesting with leading questions. Be sure to let him hear you reflect on your own thinking. If you're bewildered (or even if you're not), express your questions, ask for an explanation, and help him develop strategies to find an answer. You might ask such questions as:

"I wonder what that means?"

"Why do you suppose that happened?"

"Let's talk about what steps to take next."

"This seems pretty confusing; how could we figure it out?"

"I wonder what would happen if . . ."

"It seems the programmer put that in for a reason—could it be a clue?"

"I noticed you got that same result every time you did . . . Could that be important?"

"You've worked so hard. Do you really want to blow it all up? What if you saved this and tried again tomorrow . . . ?"

Young children may need to think hard about questions such as these, but with skilled mentors, children of any age can eventually begin to internalize this sort of dialogue, from which they gain self-control and problem-solving skills. As youngsters move through the elementary years, they build on such early foundations and are increasingly able to profit from high-quality technology use.

Now, we should take a multiage look at one of the most promising—and also the most sorely abused and oversold—digital "tools."

The Internet and the Web: Mixed Blessings

"I was spending fourteen hours a day at my computer. I felt my life dribbling away through my modem."

"The advantage of e-mail is that I don't have to sit in some room to make myself available where students would come and have to wait around for me to get free."

Bob Brown, college physics professor [1]

"Eventually the Internet will grow up, or maybe we will. We will know when this has happened when the Net becomes invisible and we can finally stop talking about it—when it has become a place you wouldn't be ashamed to have your parents visit."

Charles McGrath, editor, *The New York Times Book Review*

Seven-year-old Jordan came home from school with an assignment to make a poster advertising a state so his classmates would want to visit there. From a library book, Jordan had chosen the state of Texas, and he asked his dad if he could look for information on the Internet. Jordan's dad helped him use a search engine, and together they evaluated and chose four sites.

From a site showing all fifty states, Jordan created a large map. Using information from the Texas tourist board, he added ranches, ports, oil wells, and topographic features. He also highlighted the town of Big Spring, where his mother had been born. One of the sites enabled him to leave messages for schoolchildren in Texas, to whom he explained his project and asked them what was "neat" about their town or state. To Jordan's delight, several students sent responses, which he included in his oral report to his class.[2]

▮ ▮ ▮

In New York City, 125 "at-risk" students were given home computers and on-line hookups. Positive outcomes included: withdrawn students conversing on-line, substitution of Internet research for television viewing, and higher enrollment in college preparatory courses.[3]

▮ ▮ ▮

Anyone who assumes that being connected to the Internet*—or any other information source—automatically assures learning is either a fool or a salesman. (This includes politicians, who, like most of us, may

*The term "Internet" is used here to denote any on-line communication system or network; the be a little of both.) Anyone who believes this invention can singlehandedly make dummies of the next generation is equally in error. If used thoughtfully, it can be useful for students who are mature enough, or sufficiently well supervised, to eschew the trivia in favor of content. But turning children or adolescents loose with a multiple personality that has barely entered its own adolescence can be risky. Carol Baroudi, one of the authors of the ubiquitous *Internet for Dummies,*[4] states firmly that children below age seven should not have unsupervised computer time. She considers eleven an optimal age for introduction to electronic communications.

The Internet offers two basic educational uses. The first is finding information, by either searching documents "published" on the Web or receiving information through electronic mail (e-mail). The second is sending information or messages, again through "publishing" on a structured Web page or on-line information source, or through informal correspondence. Both uses have advantages, and both have problems.

New Communications: New Challenges

Telecommunications come with built-in challenges. They have tended to impose one language (English) on multinational correspondence, even though the Internet is a democratic forum. So democratic, in fact, that everyone's opinion has equal weight, from seven-year-olds to psychotics to Nobel laureates. Uncritical consumers are ripe victims for innuendo, inaccuracy, and invective. No authority "fact-checks" the information.

A special difficulty—or benefit, depending on your point of view—is its "untidiness," since links have no predetermined organzation. "It's as if the Library of Congress exploded in midair . . . and we haven't arrived yet to sort out the mess," a professional librarian mused. A frustrated businessman commented that his own clicking on the Web reminded him of "a lab rat clicking for more drugs."

Like much of the contemporary social scene, connections abound but are largely meaningless and impermanent, risking a superficial attitude toward research. Plagiarism is more tempting than ever, and harder to monitor. Nevertheless students by middle-school age can profitably learn to use on-line research sources *in addition to* standard texts. One of the few studies looking at this issue gave a "cautious endorsement of on-line learning" with nine- and eleven-year-olds in seven cities. All used printed materials, computer data bases, and CD-ROM encyclopedias, but half the students also used an on-line educational service and the Internet. Researchers felt the on-line group was better at stating different points of view, synthesizing research, and presenting the broad issue. Unfortunately, this study is seriously flawed by the fact that the on-line group was composed of teachers who volunteered—biasing it in favor of more skill and enthusiasm.[5] More research with better controls would be a welcome development.

Naive Excitement vs. Information Literacy

> ***"There's all this emphasis on kids having all this information at their fingertips, with this blind naive assumption that they'll know what to do with it."***
>
> High-school teacher, New York

Neophytes in the high-tech world often mistake *downloading* for *thinking.* Not long ago I was interviewed by a reporter who was writing a piece on computers in the schools for a large national newsmagazine. He had just returned from a visit to a high-school classroom where a combined English and history class was making posters on the environment with the help of the World Wide Web. From his comments, it was obvious this fellow had been "snowed" by the technology.

"You should have seen these kids!" he virtually bubbled. "This one pair pulls up a whole page of pictures and information on endangered seals—they even had pictures of bloody cubs! The kids were so turned on—man, was it ever powerful!"

At the risk of seeming hard-hearted I had to ask, "Did their teacher show them how to evaluate the source of this information? Did he insist they gather alternative viewpoints to compare and contrast? How much critical thinking was being taught or required? These are *high-*

school students in an English class; were they being asked to write about the topic or simply paste together a poster? Sorry, but this activity (absent the bloody cubs) is more appropriate for eight-year-olds."

The gentleman acknowledged he had failed to be a critical observer. "I guess I should have thought of that. But this stuff is so visually powerful, it's easy to accept it uncritically."

Indeed.

At this writing, only one World Wide Web is available to students searching for information, and it is increasingly dominated by those organizations with the means to purchase links which will subtly guide consumers toward their products or ideas. For example, if a student is looking up the Zambezi River (the key term is called the "descriptor"), the "search engine" (information-gathering device) might send him to the advertising page of an adventure-travel company. While this trend is lamentable in many ways, and we may hope for a noncommercial alternative, it does offer opportunities for working with young people on "information literacy": critical analysis in evaluating sources of information. Students must learn to ask questions to *distinguish information from opinion or propaganda.*

Becoming an "Info-tective"

How do we teach kids this skill? Here are some guidelines:

1. Who provided this information? Why?
2. Is someone trying to sell us a product or a point of view?
3. How is the source coded (e.g., ".com" = commercial; ".gov" = government; ".edu" = educational institution, ".org" = nonprofit organization, ".mil" = military, etc.)? How might this influence our evaluation of its accuracy? Can we assume that everything from an educational institution, for example, is necessarily true? How about from a government source?
4. What possible biases may be detected here (e.g., an organization dedicated to environmental protection or a business selling a product)?
5. If quotes or data are provided, are they appropriately referenced?
6. How can we find other information with which to compare and evaluate accuracy (e.g., call sources, check authorized print sources)?
7. Does this information represent theory or evidence? What is the

other? (Even undergraduate university students in the United States have difficulty with this question.)

8. Why might some sources be more accurate than others (e.g., many professional journals are "vetted" or reviewed by experts before publication)?

9. How do the visuals influence the way we receive this information? Is emotion a part of the design? Are sound effects intended to influence our thinking?

10. Do the visuals and the text convey the same message?

With excellent guidance, students even as young as eight can begin to be critical consumers of information.

Media Literacy: A "Critical Lens"

> ***"Since negotiations with media construct our reality, our task must be to give students the skills to analyze those images which lead to ignorance and access and produce that which leads to knowledge."***
>
> Bob McCannon, Director of the New Mexico Media Literacy Project

Bob McCannon, director of the New Mexico Media Literacy Project, teaches young people to analyze media messages rather than simply accept them at face value. Across media, he points out, "fact" is increasingly mixed with opinion, with fiction, or with outright marketing. He maintains we must awaken youngsters' critical faculties beyond the simplistic stories and images so prevalent today.

One way is to discuss openly the power of technologies to manipulate thought. Through weighing the advantages, disadvantages, and biases of digital technology against other media, young people will have a better chance of becoming selective consumers rather than digital drones. Gloria DeGaetano, coauthor of *Screen Smarts*,[6] suggests it is never too early to start discussing visual messages. She believes if families regularly evaluate all their media use, children can be inoculated against mindlesssness. She suggests these criteria:

Frequency: How much time do we spend in front of the screen, and

Content: What do we watch and who makes the decisions?

Discussion: Do we regularly talk about and evaluate what we watch?

One other avenue to greater media literacy is having kids create their own multimedia productions. Putting them in the producer's seat—with the help of a knowledgeable coach—enables them to grasp the power of the message inherent in many types of media.

Electronic Communication: My Best Friend

As we saw in Chapter 6, on-line communication may substitute for face-to-face social interactions. Even the handy practice of wiring educational institutions for an *intranet,* through which students, faculty, and sometimes parents at home can communicate in-house, risks this outcome. In one such high school I observed several lonely postings made during the hours on a Saturday night when many teens are (or perhaps would like to be) socializing firsthand with others. Even at the university level, students spend more and more time on-line in their rooms, and student lounges formerly used for "bull sessions" are being carved up into depersonalized computer stations. At Vassar College, in-house communicators are known only by nicknames, and many students spend weekend evenings alone, broadcasting anonymously to anonymous others.

"After a while, it starts to be really unfulfilling," commented one student. "You learn how much of a difference it makes to see someone in person and actually talk to them."[7]

Unless all our assumptions about human nature are incorrect, the novelty of decontextualized relationships will soon diminish. Hopefully, the traditional face-to-face rendezvous will not go the way of other civilities in the contemporary social scene. For those students who are reluctant social learners, however, the situation is troubling.

Bob Matsuoka of the Dalton School in New York City, who has worked with such systems for over fifteen years, recommends four general principles to keep the "virtual school" from subverting the aims of the human one.

1. *Identity: Linking the User to the Community.* Users retain their own names, though their identity (e.g., shy vs.outspoken) may change on-line. Thus everyone is personally accountable to the community for his or her actions.

2. *Relevancy: Building on Local Content.* Matsuoka believes in the 80/20 rule, that is, 80 percent of the content and communication takes place face-to-face between people within the same physical workspace—students, teachers, administrators; 20 percent can then be on-line.

3. *Proximity: Matching Virtual With Real.* On-line contact is reinforced with face-to-face contact, so virtual communication does not replace face-to-face interaction.

4. *Accessibility: The System Is Easily Usable.* The network is set up so people can get on-line easily and workstations are readily available.[8]

On-Line Ambassadors: Good and Bad

"Hi, Kai, Marek and Margaret
"Thank you for responding to my message and telling me what biome your school is in. Could you also let me know what the dominate plants and animals are in your area. [My school] is next to the ocean near Cape Cod in Massachusetts. Although we are in a biome called Middle Latitute Deciduous Forest we enjoy a moderation of our temperature extremes because we are in a maritime environment. We also have a Web page if you would like to learn more about what we do in marine science. Hope to hear from you."

David, middle-school student, Massachusetts, to students in Colorado via e-mail

"Greetings from Eno, Finland! We are building a Webpage about traditional folk music from different schools. . . . At the moment we've received music from Croatia, Czech Republic, Japan, South Korea, and USA. I know your culture is rich when it comes to traditional folk music. So if you have a possibility to play or sing and record some traditional folk music and send a cassette to us, we would be very happy."

Internet posting, April 1997

"It takes a whole lot more work to actually stand back and let students learn on their own, and that's true of networks. . . . You need something more than proximity and ability to communicate. You need to have goals, purpose, and organization, . . . educational support and technical support."

Margaret Riel, Internet teacher-educator

On-line distance communication among students is a powerful educational tool when used well. Unfortunately, it can also be an excuse for nonsense and worse. At a workshop, "Using Computers to Teach Problem-Solving," the leader (who justified most of his recommendations with the phrases, "It's neat because it's electronic," and "You've got to meet them where they're at" [sic]) extolled the virtues of communication with students from other countries to encourage hands-on problem-solving. His students in the United States, communicating with counterparts in Russia, occupied a section of the international ether to discuss the following "meaningful" problems:

1. How to get the bubble gum, which you were not allowed to chew, out of your hair.
2. How to get out of playing with a younger brother or sister.
3. How to get a raise in your allowance without having to do any extra chores.

I am aware that "authenticity" is currently a big buzzword, but surely it can be carried too far (like to Russia?).

It seems reasonable to wait until youngsters can conceptually grasp cultural differences and realize the global import of such conversations. Even young teens require background teaching and discussion before pursuing such an activity (e.g., Where is Russia? What does life in Russia look/feel like? How is their history different from ours? What is really on Russian students' minds? What can we learn from them that might be important to our country, or what can we share that might be important to them? How can we phrase our questions meaningfully and tactfully?).

Teacher educator Margaret Riel (who is employed by one of the large telecommunications companies) reports on successful international "Learning Circles," where students work under trained teachers to discuss problems and interests. Each class picks a topic that fits with the curriculum and then researches, analyzes, and reports on it in written form to groups in other countries. For example, students in India missed their annual class camping trip because of political unrest, so they developed a virtual trip that included native animals, local parks, and environmental threats to wildlife. Students in Saudi Arabia wrote about their reaction to having their country bombed. Electronic messages from students in South Australia explored aboriginal cave art and studies of the southern hemisphere. Students in France wrote for information on the textile industry in other countries. Riel, as a telecommunications spokesperson, claims that by struggling to communicate ideas effectively to others and receiving their critical feedback, students' writing and grammar skills improved more than on standard class assignments.[9]

If homes are wired for the Internet, parents can supplement the school's efforts. Unfortunately, many schools—through inadequate teacher preparation or lack of staff—are still allowing youngsters to surf aimlessly, but you can teach proper procedures at home. Moreover, many Web sites provide useful information on educationally worthwhile sources and activities. Home schoolers and even veteran teachers reach out of their isolated classrooms to exchange curriculum ideas, lesson plans, teaching tips, and generalized support with peers all over the world.

Swimming in the Info-Sea

Valuable suggestions for parents and teachers come from Jamie McKenzie, a longtime enthusiast who left a superintendent's job to become technology coordinator of the Bellingham, Washington, public schools. He soon discovered that turning a school district into a technologically literate community is a long-term (minimum five years), expensive (a $6 million bond issue just for starters), and sometimes frustrating process. He still likes the Internet, but he terms it "the greatest yard sale of information in human history. Poorly organized and dominated by amateurs, hucksters, and marketing gurus, the net offers info-glut, info-garbage, and info-tactics. Schools that plunge students into this info-sea with nothing but mythical or metaphorical surfboards are courting disillusionment, chaos, and what beach folk call 'wipe-out!'" Before schools invest millions of dollars to provide access, he recommends, they would be wise to stop and ask, "Why?"

A survey McKenzie conducted demonstrates the gap between potential and current reality: Most output by students reveals little of interest. Content is amazingly trivial; only 10 percent of sites advertised as being "curriculum-rich" actually are. Students surfing on their own—at home or at school—waste about 95 percent of their time. But McKenzie continues searching for useful models. In one, his students developed a series of "virtual museums" showcasing such topics as "Ellis Island," which featured diversity, national origin, and immigration history of students' own families. Students continue to "curate" their museum sites, keeping them up to date and responding to queries from interested "visitors."

McKenzie reiterates that teaching students to be critical consumers of this glut of information means insisting they constantly probe for meaning. His students work in teams following a format designed to teach specific skills, with the goal being *insight.* Here are the steps they follow:

1. Questioning
2. Planning
3. Gathering
4. Sorting and sifting
5. Synthesizing
6. Evaluating
7. Reporting

Questioning: Most research simply requires students to be "word movers," for example, finding information on Dolly Madison and cutting and pasting it into a report. McKenzie suggests deeper research questions: e.g., How might we restore the salmon harvest? Which New England city should our family move to and why?

Planning: Where can we find the best information most efficiently? How will we divide responsibility? How will we sort and store findings (e.g., data base, word-processing file)?

Gathering: Only relevant information is used. Students must structure findings as they gather them (e.g., summarize and enter in word-processing file). Students must decide whether information will be gathered on-line, from CD-ROMs, or from books or journals.

Sorting and Sifting: Teams scan and organize data according to its usefulness.

Synthesizing: Students analyze findings and select the most important points; they draw relevant conclusions.

Evaluating: Students survey the entire project and decide whether more research is needed. They share and discuss new insights among team members.

Reporting: Teams decide on the most effective means to present their findings (e.g., written report, multimedia presentation).[10]

Bar the Gates When Necessary

Most adults are aware by now that a great deal of inappropriate material is available on the Internet. Teen "chat rooms," especially, where youngsters exchange information, comments, and jokes, may contain smutty, degrading, scary, or biased content. One user likened it to dropping your child off alone in a "bad neighborhood."

On the other hand, Sherry Turkle points out that parents may have a tendency to displace their own fears about teen development onto the Internet. Parental understanding, firm rules, and plenty of conversation about controversial topics are the recipe for a child who ultimately becomes a self-disciplined participant.[11]

Guidelines for Internet Use: (Post Near Computer at Home or School)

❧ Give out no personal information about yourself or anyone else to people you don't know—includes full name, hometown, e-mail or postal address, phone number, credit card numbers, hobbies, interests, etc.

❧ Be careful that what is "published" contains no names, photos, or personal information that should not be made available to the general public.

❧ No visits to general-interest chat rooms. Family visits to specific interests (e.g., collie fanciers, rock climbers, stamp collectors).

❧ Observe time limits. Twenty minutes should be enough to collect information and not offer temptation to wander.

Parents or teachers will preview sites and post a list of appropriate ones. If you wish, ask your server how to obtain control systems that can block inappropriate material. Make children a part of this decision, however, since youngsters are notoriously good at hacking their way through roadblocks if they feel something is "forbidden." With sufficiently close communication, you can learn to trust each other's judgment.

On-Line Tips From the Experts

❧ Preview sites and select or download those relevant to the assignment. At home, parents can help children with the process of choosing relevant sites.

❧ For elementary-age children, consider investing in software that can simulate use of the Web with preselected sites; although children are not actually on-line, the experience is virtually (oops!) identical.

❧ Help students ask good questions to conduct a productive search and decide on one or two relevant words (descriptors) to narrow the topic.

❧ If your school can afford it, the most effective way to demonstrate on-line research skills for the entire class is with a large overhead display.

❧ Investigate and experiment with the various logic systems (e.g., Boolean logic) used in different search engines. Using categorization skills and identification of main and subordinate ideas, this activity provides good mental exercise for growing minds (e.g., "python *but not* Monty"). The very processs of nesting files and making a folder for each separate topic can also teach categorization and need for precise language use.

❧ Make sure kids read the words rather than simply flipping through the pictures. Require a record of which sites were visited, with critical evaluation of the value of each. Insist on documentation of sources, just as with text material.

❧ Keep abreast of current copyright laws and make clear your expectations for appropriate referencing of sources.

❧ Advise young people of the hazards of inappropriate e-mail postings. Two boys in a Missouri high school sent a threatening message one morning to the president at the White House. That afternoon, the Secret Service had the boys in custody.

❧ Teach children that the rule "be careful when you talk to strangers" still holds true in unsupervised cyberspace.

Having laid this groundwork, it is time now to return to a consideration of what, specifically, works and doesn't work for students who are of an age to profit from a wide variety of technology applications.

Primary Years: Good Beginnings

> *"No, no, a thousand times no. Please dismiss any notion of getting second graders ready for life. . . . Ms. Class entreats you to nurture the children as children, not as miniature stockbrokers and bankers. Life is today, not tomorrow. Primary teachers should concern themselves not with good results but with good beginnings."*
>
> Susan Ohanian in *Ask Ms. Class*[12]

> *"If you're really careful, computers and calculators can help with beginning reading, writing, and math."*
>
> Kay Dunlop, first-grade teacher, Shaker Heights, Ohio

If parents or teachers are determined to use computers with this age group, they must choose carefully. Because the brain has a particularly sensitive window of development around ages five to seven, digital forays should be carefully planned.

The "Five to Seven Year Shift"

> *"Our lower-school teachers feel the computer is a distraction. Kids need more concrete experiences. They can do spreadsheets, with the help of an adult, and hypercard, but they'd be better off fooling around with a piano."*
>
> George Burns, Technology Director, Bank Street School, New York

Have you ever noticed the vast differences between most five- and most seven-year-olds? The pronounced changes that take place in the brain around the start of formal schooling are commonly termed the "five to seven year shift." The brain is able to reason more abstractly, outgrow most "stimulus-bound" behavior, understand and enjoy mastering new symbol systems such as written words, math equations, or, finally, computer applications. Contrary to some adult expectations, however, this development doesn't magically arrive with a birthday. Moreover, even a seven-year-old brain still has a long way to go in development of control centers, higher-level association areas, and the important membrane that links the right and left hemispheres for adult attention, memory, abstract creativity and problem-solving.

Many children aged six and seven still tend to focus on one cognitive activity at a time; they may read words out loud without simultaneously thinking about the overall meaning or may have trouble relating numerical equations to real-life problems ("story problems"). Likewise, while they can learn (or figure out) new computer applications, they may be so focused on the mechanics that they fail to learn the desired content.

Even older children may forget the task at hand when confronted by computers. An Internet posting by teacher Tom Woods illustrates how gadgetry fascination is often too much, especially for reluctant readers (who may have a "developmental lag" in language).

"I was recently working with a fourth-grade student who reads at the second-grade level," Woods relates. "I started her out with a marvelous interactive fiction story on the Web called 'The Neverending Tale.' The use of the computer was highly motivating. The student could choose her own pathway through the story and even respond, if she wished, by contributing to the story herself. I found myself getting very frustrated, however, because I could not control where the student went. She was more intent on clicking buttons and highlighting text than she was on actually reading, which is what I wanted her to do. I reverted to more conventional reading material."[13]

Some technophiles would argue that the teacher should respect this child's need to explore; they would find the pathway she crafted more "authentic" because it represented her interests. In this view, her teacher should let her point and click to her heart's content, dropping his own selfish (and obviously verbocentric and controlling) agendas. I vote with Tom Woods, however, who believes his job is to teach this child to read.

Celeste Oakes, first-grade teacher in Henderson, Nevada, stoutly defends the value of two-way telecommunications for her language arts class. "I try to immerse beginning readers and writers in language experiences of all kinds," she says. For Oakes's students, electronic communication is only a small part of a rich mix. With access to only one computer, she started by having selected outside correspondents send messages to the class. Many students were eager to attempt reading the messages themselves, and they helped compose responses as Celeste typed them. As they connected with "key pals" (electronic pen pals) in Alaska, they practiced asking good questions and finding information off-line. They began seeking information about Alaska on an "Ask the Scientist" service, collecting data for graphing activities, and practicing hands-on map skills. Finally, they were able to connect to the computer aboard the space shuttle while it was in orbit, reading daily postings and even asking a question of the astronauts. This teacher gives the new technology high marks for motivating and informing her students. "They have taught me that the only limitations to using telecommunications with young students are those we impose ourselves by failing to empower them," she concludes.[14]

Another example comes from a recent study, in which a specially designed package helped six-year-olds improve "phonological awareness," a prerequisite for reading success. Not only did the children learn to discriminate and sequence the sounds in words, but they also significantly improved in word-reading ability over a comparable group using nonlanguage computer activities.[15] We should keep a close eye out for other developments of this type.

Brain-Appropriate Technology for Elementary-Aged Children

"The tulips emerged through the ground today—add that to the data base!"

Eight-year-old student, St. Louis, Missouri

I have traveled to another technology conference to learn about new methods for teaching with computers, and I am feeling discouraged. In the past two days I have quickly outgrown my initial excitement over presentation software (pedantic outlines look alike—no matter how much they pulsate) and multimedia reports rich with other people's clips and impoverished of language and originality. I am tired of educators who are so dazzled by stamped-on glitz that they lose all critical faculties. I have just come from a talk by two peppy elementary school teachers who explain how to "Build Character with Technology" by creating T-shirt decals printed with uplifting slogans. I am wandering the halls, looking for a session that will answer the question I have just scrawled in the margin of my notes:

"How much intellectual rigor must we sacrifice in order to get kids 'motivated'?"

At this point some benign digital fate leads me to Bob Coulter, who teaches eight-year-olds at the Forsythe Elementary School in St. Louis, Missouri. He actually started his session—to my surprised delight—by discussing the rationale, developmental goals, and critical assessment of technology use in his classroom. Here is a teacher clearly committed to the computer as a vehicle for intellectual challenge as well as for teaching the "basics." In partnership with Joe Walters of TERC (Technology Education and Research Centers) in Boston, Coulter engages his students in Internet projects because he finds that communicating with an external audience "pushes them to think more deeply."

TERC is a pioneer, and Coulter's students use telecommunications for projects spanning the curriculum. One that captured my fancy was a global study of wildlife migration called "Journey North." As spring approaches, students begin tracking the visible signs (e.g., tulips emerging or birds coming to the feeder) and entering them into a global data base; the information is transferred to a computerized world map which graphically displays the season's progress north from the equator as students all over the world enter their sightings. They practice real-life application of geography skills as they record the progress of the bald eagle by latitude and longitude and transfer it to a paper map in the classroom; they also make predictions about weather and length of day.

mation on animal species and meteorology. They read both on- and off-line, integrate math and arts projects such as illustrating their maps. They also "talk" on-line with real scientists, of whom they are encouraged to ask intelligent questions.

Needless to say, Coulter's good results didn't come about simply by getting his classroom "connected." When planning units of study, he follows certain important steps:

1. Developing a clear purpose that fits the curriculum
2. Determining what is appropriate for the age group
3. Planning use of a wide variety of supporting materials
4. Working out the logistics of scheduling time for the on-line and classroom activities

He is also careful to observe that his students continue to do well on standardized achievement tests.

Coulter is sufficiently objective to admit that such units are never free of problems. Moreover, he says that trying to graft this type of learning onto a "drill-and-kill" curriculum is doomed to fail. In his classroom, students use the computer to construct knowledge; they see it "as an integral tool for study, used in conjunction with other resources"—not the least of which, I might add, is a hardworking and talented teacher who understands the special needs of elementary-age students.

Ages Eight to Ten: Learning From Many Technologies

> ***"Why are we doing things on computers that we don't need to do on computers? We have to simulate a trip to Africa, but we don't have to simulate playing an African game that involves moving stones around in a certain way. It's scary to me that some kids prefer the simulated on-line game to the real one with the real stones."***
>
> Eric Robertson, technology consultant, Minnetonka, Minnesota

> ***"The kids got more excited about the audio and the little buttons than about what I wanted them to be excited about."***

Children aged eight to ten are still concrete and literal thinkers: they love mastering routines, data, rules, order, and demonstrating their competency. Generally industrious and product-oriented, they enjoy completing long-term assignments and showing off finished work. Intensely curious, they like to investigate topics such as animals or the environment. By age ten they are generally competent with concrete learning (e.g., mechanics of reading, writing, and math) and need to branch out. This seems an appropriate time for multimedia applications, research skills, and manipulating data bases or spreadsheets. It is also a good time for quality software to review the basics and fill in missing pieces, such as practicing spelling patterns and math "facts." Both at school and at home, preteens still need plenty of adult scaffolding.

Intensely interested in mastering information, they tend to enjoy learning aids such as digitized encyclopedias or guided Internet searches—which may be counterproductive if the reading level is too frustrating. They take special pleasure in research that has value in the eyes of adults and/or some practical use in the real world.

With long-range neural circuits still maturing, elementary-level students must work hard on cross-modal linkages (e.g., imagining visuals while reading a text, focusing on text screens when there are buttons to click on), reasoning about several things at one time (e.g., remembering what you're writing about while struggling to keep your fingers on the correct home keys), and understanding things from different perspectives (e.g., why your mom won't buy you that video game). They are easily distracted from academic tasks by enticing visuals or silliness in software, and they cannot be expected to plan and execute long-range projects without support. They may still be quite hazy on abstract categories, such as the difference among cities, states, countries, and continents; the magnitude of distance around the globe; or cultural differences among countries.

Because most take readily to technology routines, we may overestimate how much they are actually getting from them. Good learning activities for elementary students should include the following: a large component of real-life experience, plenty of integration across learning modes (e.g., text sources, hands-on activities, music, writing, and visual arts), checks on comprehension and use of time, and structured follow-up. Here is a small sampling of interesting projects:

❧ Eight- and nine-year-olds followed on-line a real-life recapitulation of Amelia Earhart's flight as part of a study of heroes. They also made a large classroom map of her trip, read related books, and wrote stories about possible reasons for her disappearance.

❧ Beginning Spanish students entered selected Spanish-language Web sites, experimented with translation programs, and used vocabulary-building software.

❧ One family introduced their ten-year-old daughter to the spreadsheet program by which they keep their tax records. They taught her how to keep track of her allowance by categorizing and entering her expenses. She enjoyed the "grown-up" feeling of mastering an adult skill as well as the improvement in her math grades.

❧ Students worldwide participate in "author chats" during on-line interviews with favorite authors. The children type in their questions, and the author attempts to answer as many as possible in a limited time. Needless to say, these interchanges lack something of the personal touch and communication gets somewhat disjointed with thousands of excited kids simultaneously trying to write to one person, but teachers report they spur students' interest in reading. I would like, however, to see more preteaching and screening of questions ("What is the hardest thing about being an author?" vs. "What color is your dog?") before students go on-line.

❧ Peggy Oglesby, special education teacher in Anderson, Indiana, took a group of enthusiastic students on a virtual field trip into space for a unit on space travel. They viewed satellite pictures and did research on planets. Oglesby says the added visual information helps the learning disabled grasp concepts more readily than text.

❧ Jan Frank, of Bellingham, Washington, took nine- and ten-year-olds on a similar "trip" to "Island Regions of the World." They visited Tahiti and developed original travel brochures. This type of assignment is interesting for students of this age (at least until the novelty wears off) and is educationally useful as long as the teacher sets clear standards for quality and some objective means of assessing learning.

❧ Youngsters help their families decide on the destination for trips or outings by making up sample travel brochures from selected information sources. In some cases, children have collected useful data to help with a family move.

❧ One mom who was learning to use a data base program for her Christmas card list worked along with her daughter to develop a personal address book and enter current data on the girl's friends such as address, hobbies, pets, birthdays, and favorite movies. They had some fun, some major frustrations, and learned some ancillary math skills as they finally triumphed in printing properly sized mailing labels for the daughter's birthday party invitations.

❧ Some elementary-age children enjoy preparing a regular family newsletter (possibly using desktop publishing software) to be delivered electronically or in hard copy to grandparents or other relatives.

❧ A technologically adept father told me he had programmed a small computer on top of the television set with challenging math puzzlers and hooked it up so that his son couldn't turn on the TV until a certain number of problems were done. Soon the son began to prefer doing the problems to watching TV.

❧ Another dad and his seven-year-old daughter played chess together against the computer. "Occasionally, we won!" he beamed.

How Do They Learn to Use It?

> ***"Sometimes we feel we've gone real slow, not having technology available as fast as we should. But we really don't want to 'teach technology'—we want to integrate it into the curriculum that's there. I don't like a lot of busywork and I don't want to see it on the computer."***
>
> George Cannon, elementary school principal, Shaker Heights, Ohio

Should we offer direct instruction in computer skills? One point of view insists that "computer lessons" are unnecessary, since children of this age are still experts at playful exploration and old hands at the necessary problem-solving skills. Moreover, many educators object to the decontextualized drills that often accompany "computer lessons." Thus many stration, coaching, and independent exploration. Of course, one of the inevitable thrills is periodic system failure, so plenty of technical assistance is necessary.

For this reason and because some educators believe students will not learn either the proper or most efficient use of applications unless they are directly taught, some schools hire a computer specialist and schedule "computer" as a separate class with a sequential curriculum. Some parents also send children to structured computer lessons. Both sides believe their course is the correct one; to my knowledge we have no research confirming the value of one approach or another. Certainly, if "computer" is taught as a separate subject, it should be done in close collaboration with the classroom teacher and linked to a curriculum.

Brookwood Elementary in Grand Rapids, Michigan, provides direct instruction in word processing, spreadsheets, data bases, desktop publishing, and other applications; like many schools, it has listed a comprehensive set of technology skills and measurable outcomes as students pass from grade to grade.

One of the nicest outcomes of the entire technological revolution has been to see children seriously engaged in teaching adults to use the technology with which their generation seems so attuned. The brain is ever capable of learning new things—including broader conceptions of "education" and lifelong cultivation of the playfulness and curiosity which fuel its own continuing growth!

LOGO and Microworlds

> *"The child, even at preschool ages, is in control. . . . And in teaching the computer how to think, children embark on an exploration about how they themselves think. The experience can be heady: Thinking about thinking turns the child into an epistemologist, an experience not even shared by most adults."*
>
> Seymour Papert [16]

An entirely different approach to children's computer use is found in the philosophical stance of Seymour Papert's LOGO, which is *programma-*

dren's best learning comes from open-ended "play" in programming the computer, which he calls the "Children's Machine." Rather than manipulating a program designed by someone else, the child assumes full control.

Overall research on LOGO is inconclusive, and generally more negative than positive as to learning outcomes. Yet because the theory behind LOGO runs so contrary to most institutional conceptions about how children should learn, it has rarely been implemented as Papert intended. Turning children loose to "construct knowledge" without direct instruction and being patient until that event occurs doesn't fit very well into educators' plan books—or perhaps into reality. "But nothing can be more absurd than an experiment in which computers are placed in a classroom where nothing else is changed. The entire point . . . is that the computers serve best when they allow everything to change," argue LOGO supporters.[17]

In her book delightfully entitled *Minds in Play,* Yasmin Kafai describes a long-term study in an inner-city magnet school in Boston as sixteen nine- and ten-year-olds worked in their math class one hour a day for six months designing a video game to teach fractions to younger students.[18] First they were asked to imagine, plan, design, and develop a game scenario (one example was an adventure in which the hero had to solve fraction problems to avoid being "sent flying to the underworld"), keeping a daily journal of their progress. Then each child spent approximately ninety-two hours programming it in LOGO. Next they each developed a marketing package, complete with ads and attractive packaging.

While most of Kafai's students thoroughly enjoyed the experience and produced some original and fanciful programs, they predictably tended to focus more on the visual design and graphics than on the math. In fact, they ended up learning less about fractions than a control group in another classroom where children spent their time using LOGO to design instructional software rather than a video game.

LOGO has spawned not only a corps of enthusiastic acolytes, but also an entire family of software and related activities (e.g., Lego-LOGO), and is still budding with innovative offshoots. The aquatic "Microworld" which we saw in Chapter 6 is only one example of programmable environments where youngsters "construct" rules about complex topics such as systems theory. Work continues at MIT, where innovators like Mitchell Resnick continue to develop "objects to think with" such as small programmable plastic "bricks" which can be assembled to create inventions, robots, or self-propelled toy vehicles.

A cadre of dedicated teachers endorses this approach to learning. Marian Rosen, who heads the technology program at Conway School in St. Louis, Missouri, starts children on simple programming in kindergarten. By age ten or eleven, working in pairs, they create, build, and program their own Lego constructions complete with battery packs, sensors, plastic studs, gears, axles, and miscellaneous "junk."

"In our last session we had a drill, an exercise machine based on a conveyor belt, and an original car wash complete with rotating wheel washers, overhead to-and-fro rag rack, and drying fans. Others accept a challenge such as building a machine that will lift or drag more than thirty pounds or one that can balance on a single wire stretched across the room," she reports.

To accomplish these complex constructions, students must first write many subprograms and combine them sequentially. Even eleven-year-olds still need help, Rosen finds, but they are learning valuable habits of thinking along with math and physics.

Ultimately, "the kids are part of a feedback loop they have created between the [invented] machine and the computer. To be successful at this kind of programming, students have to program their ideas in meaningful chunks. . . . That is a wonderful arena for modeling very important ideas about modular thinking."[19]

Technology and the Middle-School Brain

The image is a little unclear, but the twelve-year-olds surrounding the computer don't complain. They are too busy following the action on the screen where a disheveled-looking young man in bicycling clothes stands amidst a jungle talking earnestly with someone in a bush jacket who appears to be a scientist. They are conversing about some sort of ancient ruin nearby.

One of the students giggles, pokes another, and attempts a whispered comment, but he is rapidly silenced.

"Shush, Damon. Don't be such a jerk. We can't hear!" hisses his neighbor.

What has inspired such serious academic purpose among these kids? They and their teacher are involved in directing (along with others around the globe) a three-month bicycle expedition, manned by a team of cyclists and scientists, through the jungles of Central America in search of lost Mayan civilizations. At the moment, they are debating the possibility of sending the team through a difficult, untraveled jungle track to a special site. How fast can they ride? How far? What obstacles will they encounter? What are the odds of success? What plans must be made?

"MayaQuest" utilizes on-line and satellite phone communications to establish real-time links between students around the world and the adventurers. Because students' votes actually determine the course of the journey, they must problem-solve right along with the scientists. To acquire the necessary knowledge, the class has plunged into a variety of topics: history, archaeology, visual arts, math (e.g., Mayans calculated in base 20), science of flora and fauna, Mayan poetry, building a miniature rain forest, reading the daily journals of the adventurers, researching, developing theories, and debating about why the civilization collapsed. Meanwhile, they are learning teamwork as well as academic skills. Teachers and students are enthusiastic about such possibilities for enhancing classroom work through global adventure.

Technological "Ramps"[20] *From Concrete to Abstract Thinking*

> *"The goal of computer software should be to help students extend what they know from familiar, concrete contexts to less familiar, abstract contexts by cybernetically linking more familiar representations to less familiar ones."*
>
> James J. Kaput in *Software Goes to School*[21]

Middle school brains are particularly suited for broader experiences

Starting around age ten new connections prime the brain for more complex thinking. A spurt in frontal areas helps link thought and action, inhibit impulsive responses, facilitate planning ahead, manage motivation, and understand things from a more global perspective. Most youngsters also improve intermodal processing (i.e., being able to combine senses effortlessly),[22] so they can learn content without being quite so distracted by the mechanics of the machine or the software (e.g., reading from a screen and taking notes). In the face of powerful visual displays, however, even adults may have trouble holding a question in mind or resisting an alluring digression.

The intellectual job of the middle-school brain is to start divorcing itself from total dependence on concrete experience, learn to reason about things that can't be seen, touched, or physically manipulated (e.g., a metaphor, a scientific hypothesis, concepts of ratio, proportion, and probability), and deal with abstract symbol systems (e.g., rules of grammar, algebraic formulas). Note, please, that I say "start," as this process takes a number of years. Well-designed technology can help by providing cognitive "ramps" from the concrete to the abstract. "Intelligent tutors" may scaffold understanding in mathematical and scientific principles that are hard to simulate in real life. Cognitive scientist David Perkins and his group in Boston are developing open-ended software for older students exploring difficult notions such as proportion, velocity, volume, and mass, as well as geometric theorems. Teachers and students in Scotland, Norway, and Australia have found these applications productive. "With good pedagogy as the guiding goal," the researchers report, "technologies can be employed selectively to . . . present dynamic visual models of key ideas, to help students gather and display data, to allow them to construct and manipulate screen 'objects' such as graphs or geometric figures, and to give teachers and researchers a window on students' thinking and learning."[23] This latter point is one too infrequently mentioned, since computer use should ultimately provide better understanding of our own learning processes.

The usual caveats apply. Even most high-schoolers are not ready to be plunged totally into virtual learning environments; they still need real-life relevance and physical experience. Learning biology or physics only from a screen might even be dangerous. Neuropsychologist Sid

Segalowitz of Ontario's Brock University, who is enthusiastic about computer applications for young adolescents, explains that because this is the time when frontal lobe maturation is peaking, we must be careful about *overdeveloping cognitive functions at the expense of social behavior.* "A curriculum that divorces cognitive content from the appropriate affective [emotional] load is dangerous business," he reminds us. Witness the aggressive, antisocial statements by computer-intensive people on the Internet.[24]

For teen-aged students, structured opportunities for cooperative group work are especially important. Like all of us, they learn better when they feel some practical purpose or personal relevance in the material. Yet because brain development gives them a more abstract "window on the world," they can also be intrigued by topics transcending their immediate environments and problems to which there is no obvious "right" answer (e.g., discussing the pros and cons of an issue such as whether advertisements should be permitted on the Internet; learning about "media literacy" through examinations of hidden bias in online information sources).

Caution: "Scaffolding" Still Needed

Since these youngsters may still be relatively uncritical judges of quality of material, we must teach them to winnow the worthwhile from the foolish. They may tend to put too much faith in anything they see in print or hear from an "authority," so we must teach them to be good, critical questioners.

Some teens still need adult guidance for material they view or download. Offensive or alarming material may cause not only emotional but also cognitive problems. Neuropsychologist Jan van Strien of The Netherlands has shown that hemisphere use is easily altered by negative emotional stimuli, such as unpleasant films or "horrifying" music, which prime the right (more emotional) hemisphere, increasing heart rate and secretion of salivary cortisol (part of the "fight-or-flight" response). On the other hand, nonthreatening verbal tasks prime the left (more logical-linguistic) hemisphere. When academic tasks were given to van Strien's subjects after either positive or negative priming, their hemiside had just been stimulated. In other words, students who have recently viewed violent or unpleasant material may have neurophysiological blocks for left-hemisphere tasks such as reading, writing, or math calculation.[25]

"Ramps to the Abstract": Real-Life Applications

Some of the interesting and age-appropriate projects I have come across include:

❧ At New York's Mott Hall School for science and math, teams of twelve-year-olds developed independent science projects to form and test a hypothesis related to what they had studied. One group was interested in chemoluminescence, but their experiment ran into problems, and too little information was available to solve them. Finally they located an expert in another state and fired out a desperate query on the Internet. The gentleman took the time to respond in detail, leading them gradually through the steps of the experiment. When, at its conclusion, they discovered that their initial hypothesis had been wrong, they were disheartened—until their new friend informed them that they had behaved exactly as real scientists do.

❧ Two brothers living on the East Coast of the United States collaborated with their parents to plan a driving trip for the family through selected national parks. The boys located research and historical information, figured daily mileage, noted potential hazards, listed local wildlife, recommended campsites and nearby restaurants, predicted the probable temperature range, and prepared a booklet of information. The boys learned a great deal and basked in the importance their efforts had in making the trip a success. (Tip: If children use computers for map study, keep a real map and globe nearby.)

❧ Ten- and eleven-year-olds took laptop computers outdoors for a geology unit in Kirkwood, Missouri. Having learned to compile data bases, they observed, classified, compared, and contrasted soil types and rock samples and created a hypercard stack. In demonstrating practical application of what they had learned, they had a chance to practice measuring skills and work cooperatively with a partner.

❧ At Alexander Dawson School in Boulder, Colorado, middle-school students collaborated via the Internet with the Denver Museum of Natural History in designing a hands-on exhibit on volcanoes and geysers, which drew 10,000 student visitors to the museum. Working in teams, they collected and organized information from a variety of sources, including on-line interviews as far away as Iceland. Armed with this knowledge, they designed and created a plan for the exhibit which they constructed at school with plywood, fiberboard, papier mâché, and random materials including desk seats from their classroom. They produced an accompanying audiotape. When museum personnel complimented the fruits of their labors, the youngsters beamed with pride, and their teacher suspects this lesson is one they will not soon forget.

❧ At Horace Mann Academic Middle School in San Francisco, California, Chinese-American students communicated around the world in Chinese characters, tutoring on-line pen pals who wanted to learn English. Their English skills improved, as did their appreciation of being bilingual and bicultural.[26]

❧ Students in Bisbee, Arizona, converted their hyperstacks related to curriculum units to videotape to produce programs for a local television station. They learned skills in visual composition, lighting, audio, project management, and interviewing techniques.

❧ Marian Rosen's LOGO-centered building curriculum extends into the middle school. Having mastered machines that combine wheels and axles, pulleys, gears, and inclined planes, "They programmed remote-control cars to go in four directions; mix masters that smash cereals with variable speeds; lifters that raise well over twenty pounds; a ski lift that was a triumph of ingenuity; bouncer cars that reversed directions when their sensors were hit; cable cars suspended on twine and controlled by a joystick made of sensors. Science concepts included friction, feedback, mechanical advantage, gear and pulley ratios, tension, electricity, and design."[27]

❧ The well-known (and heavily funded) "Archaeotype" program at Dalton School in New York City puts students in the role of archaeologists on a dig. They work in teams to access and analyze multiple sources of information (electronic, print, and human), and communicate between classrooms to develop questions and solve problems.

adventures that students follow and participate in on-line. In addition to "MayaQuest," many students around the world follow on-line Project Magellan, a real three-year voyage around the world that replicates Magellan's journey. As part of this virtual adventure they receive raw data from which to draw conclusions: pictures, journals, scientific observations, and direct correspondence from the scientists actually taking the journey.

❧ Thirteen- and fourteen-year-old students in a "gifted" class at Twin Groves Junior High School in Buffalo Grove, Illinois, participated in a Virtual Renaissance. They used an annotated listing of Web links and other resources to create a Web site related to their study of Shakespeare and his times. Students practiced skills of project planning, information retrieval, critical evaluation, documentation of sources, and expository writing, as well as demonstrating their understanding in creative skits and presentations for the class. The study was carefully planned and closely directed by their teachers (who refer to themselves as "coaches") and involved the class with Renaissance art, architecture, drama, law, literature, medicine, styles of dress, music and dance, science and math.

❧ Jack McGarvey's students in Westport, Connecticut, use animation to tell a story without words as they study plot, or to make geometric concepts come alive with lines flying together to form colorful twirling cubes, triangles, and trapezoids.

High School and Beyond

"Once upon a time, college libraries were sacred places for research. But now, as cheap, bright and easy electronic information swirls around a youth culture steeped in entertainment values, it is easy to fear that the very purpose of libraries is being torn asunder. Given the weird mix of amusement and genuinely useful information in the Web, it's a nettlesome call for an educator."

Peter Sacks, college professor and author of *Generation X Goes to College* and college students—as in the general culture—is still a hot topic for debate, most people agree that new technologies are an important and valuable adjunct in the education of older students. In my opinion, it is ridiculous to be giving computers to young kids when teens, who can profit both practically and intellectually from their use, lack these resources.

At around age sixteen (with wide variation among individuals) the brain is on its way into adulthood. Although significant developments will continue for some time, students by this age should have a broader perspective and a growing ability to ponder trends, issues, and moral dilemmas. These years represent an ideal time to study the history of science and technology as they affect human cultures. Just as our young people embrace new developments, they also need to consider critically the fact that for every technology we add, something is irrevocably lost. Veteran teachers might delight at the prospect of a multidisciplinary course incorporating such questions as how different media affect thought and societal development, the cultural/economic/political implications of technology use, whether our current technologies amplify or restrict knowledge, and how much virtual life will or should supplant the real thing. These conversations could also be very much at home around a family dinner table where adolescents and adults debate and share generational perspectives.

It is, of course, a mistake to overestimate maturation even in the nominally mature. Students of all ages revert to concrete learning when material is difficult or unfamiliar. Even high-school students may have trouble grasping the meaning of the word "yield" if they memorize it for a vocabulary test, but they will learn it readily enough when they have to take the exam for their driver's license. Thus, computer applications providing ramps between concrete and abstract are still important for this age group.

Many of today's teens are disaffected, bored, and impatient to get out into the real world, often because what has passed for "learning" has been far too abstract, passive, and lacking in perceived relevance. New technologies can provide a welcome change. Nevertheless, these are the years when high standards of understanding and precise thinking creasingly important. Working with Howard Gardner at Harvard, Vera Boix Mansilla has looked at media's tendency to blur the boundaries between what might have happened and what has been invented by a writer or director, so that research dependent on visual media (as in film clips or on-line encyclopedias) may block real understanding. When studying history, for example, "visual representations . . . may 'take us to the scene,' but they tell us little about the broader historical interpretations in which these situations must be inscribed."[28] In other words, a student must study all types of input (including written text) *within a specific discipline* to gain critical understanding.

Here are a few examples in which teachers have tried to stimulate critical understanding:

❧ Instead of memorizing a disembodied set of facts, students studying American government, economics, or related subjects join a "Virtual Congress," in which the class assumes the role of U.S. representative from their congressional district, makes decisions, communicates via e-mail with "representatives" in other parts of the country, and votes on appropriation bills. They must develop a budget for one of thirteen appropriations subcommittees using reference materials, data bases, questionnaires, and experts. The Virtual Congress is designed as a backup technology for the classroom teacher, who must actively shape it to fit course objectives.[29]

❧ Foreign-language students visiting or developing second-language "virtual world" Web sites are immersed in both the language and the culture of the country they are studying.

❧ At Emerson High School in Union City, New Jersey, a large grant from industry enabled the school to collaborate with the Center for Children and Technology in New York. Intensive teacher training accompanied installation of two hundred computers (of which, by the way, some thirty are down at any one time, requiring one and one-half full-time technical support people). In the honors U.S. history class, a unit on the Bill of Rights using the Internet required students to research one amendment and related Supreme Court cases. They then interviewed law professors, prepared oral arguments for and against defendant and plaintiff, and analyzed the constitutionality of the Supreme Court's decisions.[30]

Denine Morescki's class in Winona, Minnesota, wrote an original piece of interactive learning ware to press onto CD. Each project had to incorporate text sources, scanned pictures, original animations and digitized quick-time movies, statistical graphs, a glossary, and careful documentation.[31]

❧ At the extravagantly endowed Peddie School in Hightstown, New Jersey, sophomores and juniors—each equipped with a new laptop—pursue a year of rigorous interdisciplinary, globally networked study of a theme which "requires students to think across traditional boundaries." As students pursue projects outside of the classroom both electronically and physically (on organized trips), they learn to think critically about global issues.

❧ At High School of Technology in Wilmington, Delaware, formerly disaffected students now compete for admission. The school claims a dramatic turnaround from adding a networked system accompanied by bottom-up changes to improve teaching, reach students with different learning styles, increase community involvement, and set higher levels of expectation. Students now use graphing calculators, discover geometry theorems with special computer software, edit their own writing on word processors, and build virtual engines. A rising grade point average and a 50 percent drop in incidents requiring discipline attest to the success of the changes.

It shouldn't take a massive technology budget to show educators and policymakers that students shouldn't be spending their days filling out worksheets, as they previously were at the Wilmington school. Now students feel more interested in and responsible for their learning, and they read and write more, even in technical courses.

Says principal Henry Stenta, "Change is always interesting and challenging. Yet in the educational environment it can be threatening and exhausting. New equipment, new training, new upgrades, new, new, new—you hop on the 'up' escalalator and never look back or try to jump off. As long as instructors agree to and even embrace the ride and the administration agrees to pay for it, technology can be the successful instructional tool that we all hoped it would be."[32] Of course, might well have had similar results, even minus the expense of the new technology.

Assessing Student Work in the Age of Hypermedia

> *"Who would fail to be impressed with this display of scholarship? The [student's] report was beautifully printed on a color ink-jet printer, it was longer than the teacher's doctoral thesis, and it included the most up to the minute data available. . . . If only one report was getting an 'A' we might guess it would be the one that looked the nicest, was the heaviest, and had material not found in [usual] news sources.*
>
> *"In this case, that might be a tragic mistake."*
>
> David Thornburg in *Education in the Communication Age*[33]

"Hypermedia" or "metamedia" call for broadening definitions of "literacy" and our methods of evaluating student work. Now that students can "write" with video and graphics, educators must set standards to evaluate new forms of expression. Here are a few preliminary guidelines:

❧ Hypermedia projects should incorporate all media of concern to the topic at hand.

❧ To prevent yoking superficial elements together, teach strategies similar to those recommended for on-line research:

1. Gather information from a variety of souces
2. Evaluate quality of information and sources
3. Analyze information to detect general trends and topics
4. Develop a statement of the problem or the hypothesis
5. Select the tools for representing the information
6. Plan the steps to the solution or the finished product

❧ Students should be required to *elaborate* the knowledge they have gained, rather than simply copying and pasting it or answering multiple-choice questions (e.g., develop an original graphic representation of the topic; apply the information in a new context). After studying the human digestive system, middle-school students created original computer models, drawings, or animations of it and wrote a creative story from the point of view of an organism—real or imaginary—taking a tour through it.

❧ Ask the students to develop visual concept "maps" or brainstorm all they know about a topic at the beginning of the activity to set a framework for the content to be covered.

❧ Use the technology to help students visualize and interpret data (e.g., when making science charts or graphs, use a spreadsheet program to create three different types of graphics using the same data).

❧ With the new ability to cut, paste, and download directly from print sources, firm policies on plagiarism must be articulated for teachers, parents, and students to understand.

❧ One of the best ways to ensure original work is to ask the student to summarize the entire topic—either orally or in writing. In the electronic era, the "A" reports may be those which do the best job of synthesizing information from various sources.

❧ Consider setting a *maximum* number of pages for a written report in addition to a *minimum*.

❧ Try to overcome the natural tendency to judge an assignment by its physical appearance—no longer a guarantee or even an indication of student effort. Some of the fanciest products may represent shallow work.

What Became of Handwriting, Spelling, and Math Facts?

If any single issue divides the new technophiles from the hoary traditionalists, it is the question of how much we should allow electronics to substitute for basic competencies in writing, spelling, and calculation. As usual, the question is not easily answered, but developmental learning needs can guide decisions.

Writing and the Word Processing Wars

"I love computers because for one thing I can get words down

spelling and when I type on the computer I don't have to take a long time to work on [them], and there's all the cool things you can do with a computer to make your writing the way that you feel good about."
Middle-school student

"It's hard to believe they spend an hour a day on keyboarding in grade three, and then we have to totally reteach it when they get to grade seven. Something's clearly wrong with our curriculum!"
Middle-school teacher, Colorado

Almost everyone agrees that students should acquire skill at word processing, but almost no one agrees on whether, when, or how keyboarding (touch typing) should be taught. I have been circling through schools, interviewing "experts," questioning teachers, searching out research, and watching kids of every age banging on keys, and I have yet to come up with a completely satisfactory answer. Here are some examples that illustrate the range of opinion I have heard:

"Start teaching keyboarding as early as possible! Forget writing with a pencil!"

"Horrors! Pencils first!!!"

"Forget keyboarding! They will pick it up by themselves."

"Keyboarding will soon be obsolete—we'll be using a stylus or dictating directly into the computer. Teach oral language!"

Somewhat dazed by these clashing opinions, I requested some guidelines from Judy Royer, computer teacher at the Copper Hill Elementary School in Ringoes, New Jersey, who has plenty of real-life experience to back up her colorful opinions. ("I've been teaching since they invented water," she modestly states.)

"Teaching keyboarding? Oh, that's such a bugaboo. Ask me today, I'll tell you one thing, and probably another tomorrow. Maybe best around age eight or nine? But they don't need a $3,000 machine to learn keyboarding. Personally, I don't use children's typing programs because those cutesy graphics take too much time away from the learn-when they're supposed to be concentrating on where to put their fingers.

"But they have to learn it sometime. We don't want them in high school saying 'There's no "j" here . . .' "

A Tentative Synthesis

Lacking definitive guidelines, I have attempted to draw up a tentative synthesis of experienced voices, research, and clues from child development.

WRITING ON A COMPUTER VS. WRITING BY HAND: MORE WORDS, BUT HOW'S THE QUALITY?

> ***"I do not think that computers make you inspired, though it makes you distracted. You get more caught up in what font you should use, how big your title should be, and how big or small your text should be, than what your even going to write about, and how your going to use that stuff."***
>
> Kiera, age nine, Colorado

Let's start by discussing the process of writing as opposed to the act of handwriting, which we'll come to shortly. Some children write more words more enthusiastically and are willing to edit more thoroughly on a computer.[34] Computers are invaluable for children with organic handwriting difficulties ("dysgraphia"). "Concept" and pictorial keyboards enable nonreaders to create stories, and voice-synthesized programs help with pronunciation of words. While these latter products are still primitive, they hold intriguing potential for helping with second-language development in minority children and adults, among other uses. In one recent study, nonnative lower-class children in France enjoyed "writing" stories with colorful images which were translated into words they could hear pronounced in French.[35]

Other studies paint a less glowing picture. In one three-year study, eight- and nine-year-olds generated longer and better-quality essays by changes only at the word level (e.g., using a spell-checker) as opposed to substantive changes in content and organization.[37]

Computers will not themselves teach writing skills. Laura Nader, professor of anthropology at UC Berkeley, remarked at a recent conference that she finds college students who have had computers since primary school tend to write papers that read like annotated bibliographies. They have abundant references but lack judgment on how to rank them, how to synthesize a thesis or defend a position.[38] For younger children, however, on-line writing may inspire efforts at clarity, because one can't get by with facial expressions, body language, or the ubiquitous "You know." Thus students must be more explicit in language and learn to consider a message from another's point of view. Because students often take seriously the idea of being "published," they may also put more effort into the finished product. Nevertheless, electronic writing places special demands on teaching. After years of exhorting students to write more, we are now forced to teach them to express more by writing less. Some teachers appreciate the structure that mind-mapping, outlining, or "idea" software brings, but others believe students should learn to organize their own thoughts.

Clearly, no consensus exists. Moreover, writing for hypermedia makes new demands for integrating text and graphics. Eventually, we may have an entire new set of teaching methods and new standards for the old-fashioned process of "writing."

Whether to Teach Keyboarding Skills

As the parent of a son who hunt-and-pecked his way through high school, college, and law school with speed and accuracy that rivals that of good touch typists, I find this question difficult. I have seen ten-year-olds who have intuitively mastered the keyboard on their own. Nevertheless, for most students, it is probably useful to follow some structured method of learning keyboarding, but mastery requires maturity and perseverance.

"I worked at it," one girl informed me with a certain degree of satisfaction as she zipped through her assignment. "These other guys goofed off, and now they still have to look to find the keys."

When to Introduce Keyboarding

Efficiency should be our goal in teaching any skill: Strike while the neurological iron is hot—soon enough to forestall bad habits but late enough to have it stick with a minimum of time spent. Somewhere around ages nine and ten, many children are able to coordinate body and brain sufficiently to maintain a hand position and manipulate keys without undue difficulty; prior to that time, many will simply be wasting time and developing bad habits. Experienced teachers tell me that only by age ten do children have the maturity and patience for independent practice. I also hear frequently from middle-school teachers that kids who "learned" it younger still don't know it and need a systematic review at eleven or twelve. Of course, some students may need to await more maturation, and some will be able to achieve proficiency quite early (more girls than boys seem to fall into this latter category).

One of the most neglected points in current practice is that any teaching should be constantly reinforced: If you occupy the instructional time to teach it in fourth grade, make sure they are expected to use it in fifth, sixth, etc. A schoolwide policy is a must, here. Avoid the territorial imperative. ("It belongs in third grade and it's mine!") Some schools adopt reasonable benchmarks for students to meet, such as a certain number of words per minute by the end of eighth grade, or a history report typed in good form.

One trend has administrators purchasing small, durable personal keyboards that children can carry around with them to type stories or reports. Even six-year-olds can use these "child-proof" products at school and at home. Later, they can be connected to a printer for a finished printout. According to several elementary principals with whom I have talked, they are a motivational tool for language and literacy development even when children "hunt and peck" to find the letters on the keyboard. No one I talked to had thought of the implications for children's vision, if there are any.

Should It Replace Handwriting Instruction?

Children below age eight or so should still internalize the muscular and tactile "feel" of forming letters with a pencil, marker, or crayon on paper kinesthetic learning style particularly profit from extended multisensory experience in forming letters by hand. In one study, eight- and nine-year-olds both with and without learning disabilities practiced their spelling words either on a computer, by writing, or by tracing them. All agreed the computer was more fun but felt that writing or tracing helped them learn better.[39]

How Should We Teach Keyboarding?

A synthesis of opinion and research recommends a structured, straightforward program of learning and practicing hand position on the keys. However, better results are usually achieved more quickly, at least for students up to teen years, if structured teaching supervision accompanies CAI.[40]

The Role of the Home

Here is one area where parents can really help. Many youngsters don't get sufficient practice time at school, so ten or fifteen minutes a day at home can make a difference. You don't need an expensive computer, and you can borrow, buy, or possibly download recommended software and work with the child to set up an organized practice schedule and supervise use. Don't push this on your child too soon, and if you find your youngster simply doesn't have the interest or coordination to persist, drop it and try again later.

One mother who had always wanted to try her hand at story writing learned and practiced keyboarding skills in the evenings along with her son. He was charmed to see her in the unaccustomed role of student, and his own motivation increased as they discussed together their frustrations in mastering the lessons.

New technologies tend to be used initially only in the way that the old ones were (e.g., like a standard typewriter), but imagination offers interesting possibilities.

Spelling and Math Calculation

The same developmental principles apply for spelling and math calcutile feel of forming spelling patterns in words or writing out equations in math helps children remember them. Even for older students, one of the most powerful remedial techniques for spelling and "math fact" difficulties is a "multisensory" approach: write or trace (feel the shape), see, and say, all at the same time. In math, of course, the tried-and-true manipulatives (cubes, rods, and more complex computational objects) should also have a major place in any curriculum.

Spell-Checkers

Spell-checkers and hand-held spelling aids are useful for everyone and essential for some, but they should not replace basic instruction in word patterns and spelling rules. The best spell-checkers are those that deepen processing by forcing the student into firsthand contact with the word, by having either to type in the correct form or, more frequently, to select from a set of choices.

One serious problem with current spell-checkers is that they don't understand the context in which the word appears and thus mess up royally on homophones (sale:sail; son:sun). Until these tricky little orthographic perversions pass from our language (which is clearly on the way to occurring, if you note the number of errors in any newspaper), we must still teach the words directly, get writers to use a dictionary, or decide two bare the site of fowl-ups.

Calculators vs. Calculation

Some very bright people don't seem to be able to learn the multiplication tables. Moreover, the National Council of Teachers of Mathematics has gone on the line (or, possibly, out on a limb) to recommend that calculators be used even for beginning arithmetic. Yet we have legions of middle- and high-school math teachers complaining that kids are too dependent on calculators and lack basic number sense—they punch in numbers and record an answer without analyzing it. The ability to do mental math and to make good estimates is valuable in the real world and seems at risk of being lost. Even some algebra students can't do simple problems in their head or estimate whether an answer is grossly off the mark. (One dozen oranges for $695.00?)

Simply reading or copying an answer off a calculator does not fix learning very firmly into the brain. On the other hand, figuring it out yourself, particularly in writing, moves it more deeply into memory. This fact is known as the "generation effect," for the important difference between *generating* an answer and just *recording* it.[41]

If calculators replace practice in basic skills of pencil-and-paper calculation, they lose the generation effect and thus tend to undermine development of strategies, speed, and understanding of numerical relationships.[42] At the Bank Street School in New York, math teacher Michael Wilkinson's policy is that calculators and computers be used, even for middle-school students, only when the calculations are too laborious to do manually. His students use the computer to develop understanding, as in investigating the relationship of circumference and diameter in many different size circles. After measuring scores of real-life circles, they begin to approximate the concept of pi, and the computer then helps them extend their practice.

In short, optimal learning may take many forms, depending on age, individual needs, type of learning, and available teaching materials. As we become more comfortable with our new technologies, we will doubtless learn that they serve us most effectively as supplements to—rather than replacements for—the time-tested staples of good education.

Digital Scaffolding

Our young people these days can easily intimidate us with their quick digital know-how and their worldly wise demeanor. Yet technological savvy guarantees nothing about basic skills, intellectual prowess, or mature wisdom. Trusting computers—or any other electronic medium—to instill genuine learning is an abdication of our most essential task. This generation continues to need—perhaps even more than any before it—the steady hand, loving collaboration, and proven methods of its elders.

In a way, we now have two younger generations to raise: the human and the digital. In our final chapter, we will look ahead to some of the