DOCUMENT RESUME

ED 460 678 IR 019 564

AUTHOR	Fulton, Kathleen
TITLE	The Skills Students Needs for Technological Fluency. Learning in a Digital Age: Insights into the Issues.
INSTITUTION	Milken Exchange on Education Technology, Santa Monica, CA.
PUB DATE	1997-00-00
NOTE	76p.; Executive summary is appended.
PUB TYPE	Reports - Evaluative (142)
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	*Academic Standards; Computer Uses in Education; Curriculum Development; *Educational Assessment; Educational Change; Educational Objectives; *Educational Policy; *Educational Technology; Elementary Secondary Education; Equal Education; Information Literacy; Information Skills; *Information Technology; Internet; Policy Formation; Skill Development; Student Needs; *Technological Literacy; Technology Integration; Technology Planning
IDENTIFIERS	Access to Technology

ABSTRACT

This paper looks at how the necessary technology skills have changed over time and how those changes affect the ways in which technology skills are taught and assessed. It reviews how educators' views of technological fluency are shaped by both the "pull" of technology--increasing technical power and applications that affect what workers and citizens need to know in an information society--and the "push" of content standards that affects what students are expected to learn and new views of how learning takes hold. The paper reviews the approaches various states and districts have taken to setting standards--embedding technology standards within curricular areas, or developing discrete technology skills and assessment measures--and gives examples of some promising practices. The challenge of building consensus for, and policies that support, technological fluency raises a number of issues for policymakers. These include the question of teacher competence, the amount and kinds of testing necessary to track progress, issues of equity, and implications for research. This document includes sections that cover: (1) changing definitions; (2) factors influencing today's necessary skills; (3) information literacy in the age of the Internet; (4) state and district technology skill standards and assessments; (5) technology proficiencies in promising projects; and (6) implications for policy. The executive summary is appended. (Contains 45 endnotes.) (AEF)

Learning in a Digital Age: Insights into the Issues

The Skills Students Need for Technological Fluency

Kathleen Fulton

Center for Learning and Educational Technology
University of Maryland

A Publication of the Milken Exchange on Education Technology

Learning in a Digital Age: Insights into the Issues

The Skills Students Need for Technological Fluency

Milken EXCHANGE on education technology

Learning in a Digital Age: Insights into the Issues

The Skills Students Need for Technological Fluency

Kathleen Fulton

Center for Learning and Educational Technology
University of Maryland

A Publication of the Milken Exchange on Education Technology

Contents...

I would like to thank

Acknowledgments

the Milken Family Foundation for their generous support and leadership throughout this project. I wish to thank the dozens of technology directors, teachers, researchers, and policy wonks who provided leads, suggested Web sites, and shared other resources that contributed to this paper. Their names are sprinkled throughout the citations in this paper. Special thanks go to those kind and patient colleagues who read drafts in progress and offered valuable guidance and suggestions, including Ron Anderson, Hank Becker, Michael Cady, Geoff Fletcher, David Mintz, Barbara Reeves, and Ferdi Serim. I thank you all for your help and your continuing gifts of friendship. Finally, to the two Cheryls (Lemke and Fagnano) of the Milken Family Foundation, I extend my special thanks for encouraging me to write this paper, and for supporting the efforts all along the way.

THE SKILLS STUDENTS NEED FOR TECHNOLOGICAL FLUENCY

"The Skills Students Need for Technological Fluency" is the first publication in the Milken Exchange on Education Technology series *Learning in a Digital Age: Insights into the Issues*. The Milken Exchange is an initiative launched by the Milken Family Foundation in early 1997. A nerve center for an emerging national network of educators, public officials, and business leaders advancing technology, instruction, and education reform policy, the Exchange formalizes and extends the Foundation's commitment to further the use of education technology in elementary and secondary schools. While the Milken Exchange's primary goal is to accelerate student access to education technologies that support increased student achievement, we understand that to be effective in raising student achievement such access must be accompanied by general school reforms. The Exchange's strategies target five key areas: public awareness, policy and budget, planning, instructional applications, and development and research.

The Milken Exchange has identified a broad range of important policy and implementation questions regarding education technology. These include:

- Is there a set of necessary skills that define student technological fluency?
- What kinds of technological skills must teachers develop as schools acquire more technology to support pedagogy and management?
- What public policy actions are necessary and effective in bringing education technology into schools and classrooms?

In order to gain deeper understanding and direction, *Learning in a Digital Age: Insights into the Issues* will systematically and thoroughly examine the issues behind these questions. Each publication will tackle a different issue inviting numerous national, state, and local perspectives. While we seek broad-based views, our aim is to promote a national dialogue leading to consensus and action at the state and local levels. Indeed, it is our aim that this series be useful for state and local policymakers as they construct systemic and curricular reforms that include extensive utilization of computers, telecommunications-based networking, and other technologies.

Just what are the *skills* Johnny *must* learn?

"The Skills Students Need for Technological Fluency" examines how the education establishment ensures that our students are technologically prepared for their future. The work in this paper was first presented at the 1997 Milken Family Foundation National Education Conference in Los Angeles, and subsequently at the Milken Exchange's National Forum for State Technology Leaders in Chicago. On both occasions, a cross-section of state chief school officers, technology directors, legislators, Milken Educator Award recipients, and representatives of the research and business communities contributed to the critical discussion of student technology skills. Such input illuminates all concerned citizens' shared goals and focuses our perspective.

Too often technology is promoted to the education community and the public alike as an elixir or silver bullet that will magically cure or solve American education's ills. The mass media endlessly assert that Johnny needs to be computer- and information-literate to be prepared for the technology-driven work world and the information age. Yet, they rarely ask and never answer the key questions: Just what are the skills Johnny *must* learn, and how will he, his teachers, parents, and ultimately his employer know if he *has* learned them at the appropriate level? Indeed, few issues surrounding education technology are as important as the implications of these questions.

"The Skills Students Need for Technological Fluency" details the history of efforts to address these questions at international, national and state levels, and it describes the current "state of the profession" activities in standards-setting and measurement. Numerous examples are provided, along with text and Web citations for further study. The paper ends with a summary of the policy implications for teacher training, testing, equity issues, resource allocations, and research.

Our goal is to give readers a better understanding of the complexity of student technology skills in terms of definition, acquisition, and assessment. It is not to provide answers: Education is too firmly committed to local control for dogmatic prescriptions. We offer this paper to policymakers and educators who are committed to helping school systems develop the curriculum, instruction and assessment methods that will best prepare young people for the technological age.

The computer is no longer

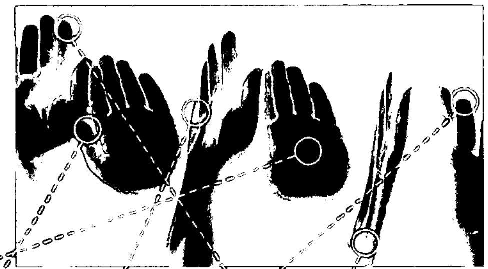
Abstract

"the new kid in school."

Since the early 1980s, when computers were first used in schools, more than $3 billion has been spent on hardware, software, teacher training, and connections. But are our students technologically literate or, as many have begun to demand, technologically fluent? These are important questions for America's success—and that of its children—in the information age, but we need a consensus on what it means for students to be facile with technology. Is there a set of necessary skills that defines technological fluency? Can this set be expanded to include the broader communication and information skills students will need in the global economy of the twenty-first century?

This paper looks at how the necessary technology skills have changed over time and how those changes affect the ways in which technology skills are taught and assessed. It reviews how educators' views of technological fluency are shaped by both the "pull" of technology—increasing technical power and applications that affect what workers and citizens need to know in an information society—and the "push" of content standards that affects what students are expected to learn and new views of how learning takes hold. The paper reviews the approaches various states and districts have taken to setting standards—embedding technology standards within curricular areas, or developing discrete technology skills and assessment measures—and gives examples of some promising practices.

The challenge of building consensus for, and policies that support, technological fluency raises a number of issues for policymakers. These include the question of teacher competence, the amount and kinds of testing necessary to track progress, issues of equity, and implications for research.



"necessary skills

for technological fluency"

defined in the past,

how it is changing,

how it is measured,

and how standards

in the field will affect

the evolving definition

Introduction

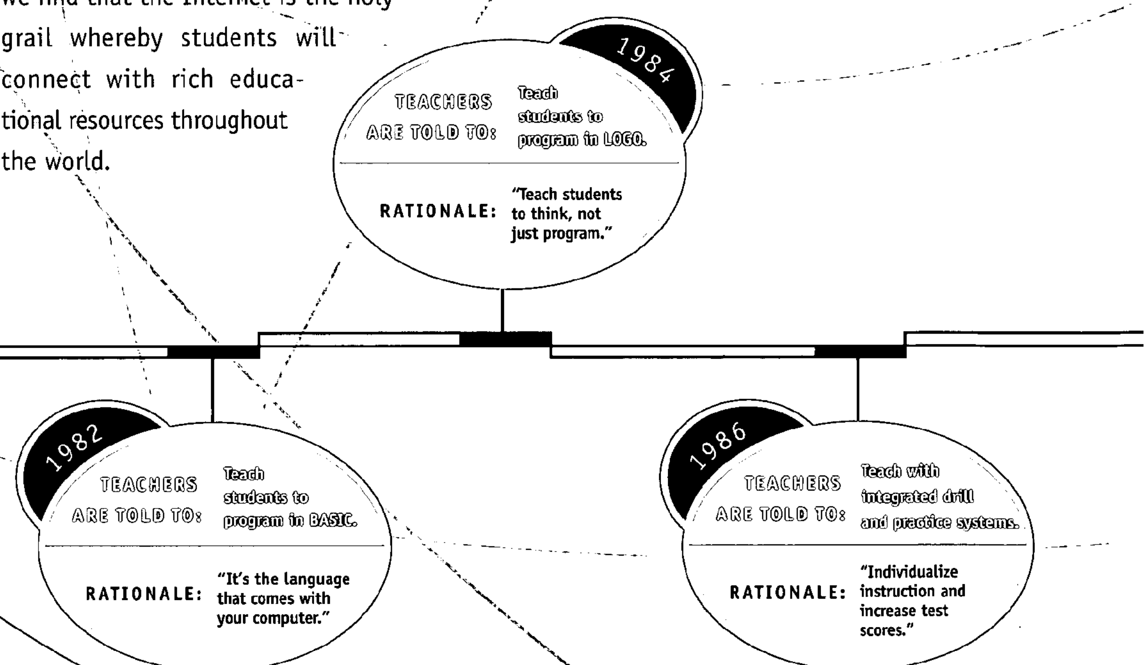
A recent hearing of the Technology Subcommittee of the Science Committee of the U.S. House of Representatives posed the question "Technology in the classroom: panacea or Pandora's box?" The juxtaposition is an intriguing one but suggests that technology is, in and of itself, either the answer to educators' prayers or a dire threat whose ramifications have yet to be understood. Like many past inquiries into technology effectiveness, it places the focus on technology as an independent variable, which is a simplistic view that researchers have come to reject. Effective use of technology is the result of many factors, chief of which is the teacher's competence and ability to shape technology-based learning activities to meet students' needs. Other factors—software, access, time to try new things—affect the impact of technology on students and their achievement, as has been noted in many past analyses.[1] But another key element, one that may seem obvious, has, in fact, been overlooked in many past studies of the effects of computer-based learning in the classroom. One recent study put it succinctly: "The effect of computer-based learning technologies in facilitating student learning and performance is seen only when participants have the knowledge and skill to use the technology."[2] The authors report that perhaps because of the "assumed power of the technology" past researchers have not evaluated the knowledge and skill base necessary for students to use technology most effectively. This paper reviews how that knowledge and skill base—what may be called the "necessary skills for technological fluency"—has been defined in the past, how it is changing, how it is measured, and how standards in the field will affect the evolving definition of these necessary skills.

Changing Definitions

What do students need to know and do with technology? Unlike the more stable content and goals we have for other areas of school study, technology continues to change and evolve. Although what students learn in first grade is almost universally standard: early reading, writing, and arithmetic skills, perhaps some science and music and art production—what students should be learning with and about technology keeps changing. The Office of Technology Assessment *Teachers and Technology*[3] report suggests a roller coaster that schools and teachers are required to ride as they attempt to adjust to the constantly changing definitions of appropriate technology emphasis.

In the early 1980s, when personal computers first were finding their way into schools around the country, we thought students should learn to program in BASIC—the language that makes a computer work (see figure 1). This was followed by a fascination with LOGO to help students think. Then came our love affair with drill and practice applications on integrated systems—to bring up test scores, individualize instruction, and, not incidentally, make technology manageable without much training on the part of teachers. But then classroom-based word-processing programs came on the scene, and educators deemed it important to teach students to use computers for composing and writing. Then came curriculum-specific tools, such as history databases, simulations, microcomputer-based labs, and so forth. Just as that emphasis was taking hold, along came multimedia, with the spotlight turned to hypertext programming so that students could create dynamic products for an audience. And now, in the late 1990s, we find that the Internet is the holy grail whereby students will connect with rich educational resources throughout the world.

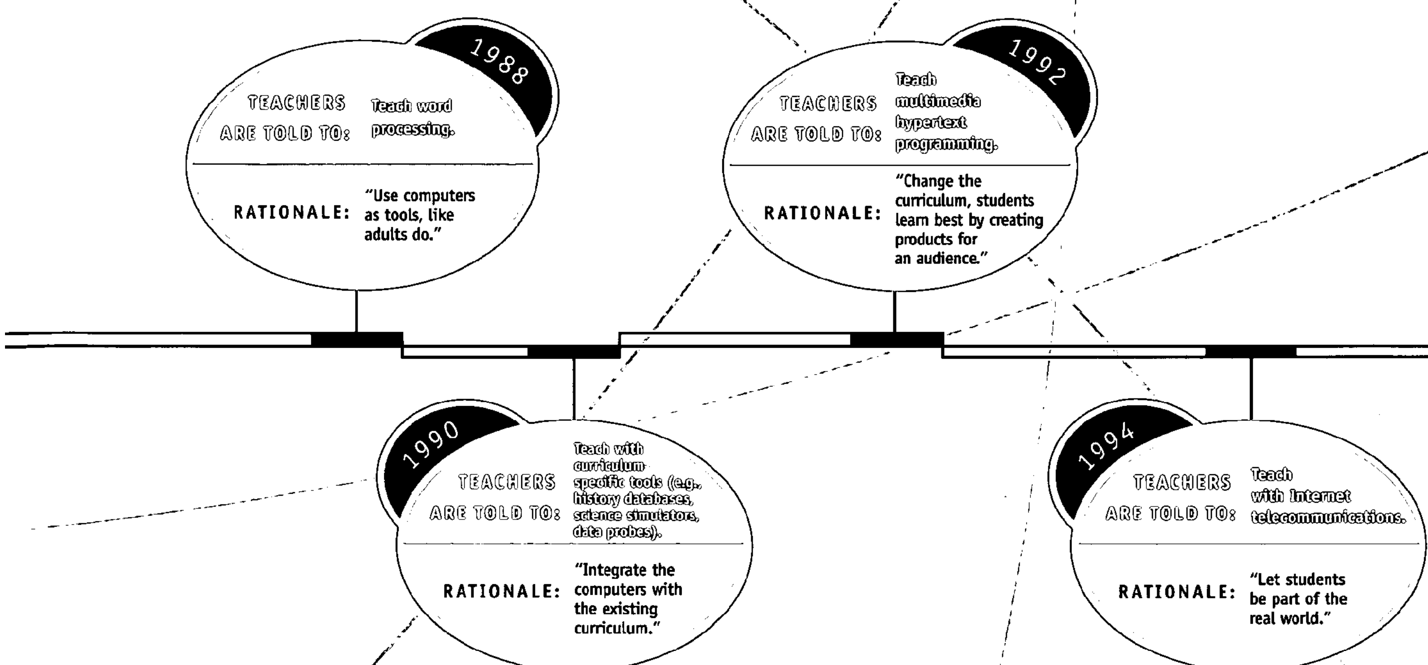
FIGURE 1



Source: H.J. Becker, "Analysis and Trends of School Use of New Information Technologies," Office of Technology Assessment contractor report, March, 1994.

How can a state, a district, a school, or a teacher keep up with these changing technology goals for students? Although it can be argued that each focus builds on the one that preceded it, just as educators get their arms around one approach, with the attendant investments in software, training and possible curricular readjustments, the prevailing wisdom about appropriate technology use changes. Indeed, this prevailing wisdom about appropriate technology use in schools is neither prevailing nor probably all that wise. Add to this the progression in hardware, getting ever more powerful and more versatile, and comparable software advances, and one can understand why the term *technology planning* might be considered an oxymoron.

Is there a synthesis developing today, or have we moved to yet another cycle of changing expectations? As educators struggle to find the most appropriate ways to employ the ever more powerful technologies available to them, several factors are creating new emphases. Today's definitions of technological fluency evolved from the intersection created by the technology pull, that is, advances in what the technology can do and how it is used in the world beyond the classroom, as well as the pedagogical push, changing views of learning reflected in the educational standards and assessments that drive instruction. To appreciate how this synthesis has evolved, and continues to evolve, let us review how past large-scale national and international assessments measured technology skills.



National and International Assessments of Computer Competence

In 1983, the landmark report *A Nation at Risk*[4] identified computer competence as a fourth basic skill. But what was meant by *computer competence*? In the early 1980s, when computers were a novelty and their workings a mystery to most users (even more so than today), the emphasis was on *computer literacy*, defined as understanding computers and knowing their parts. Because programming made computers useful, programming was emphasized. And, since the early school computer uses borrowed from those used in business, a general awareness of tools such as word processing, spreadsheets, and databases was considered important.

NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS

The first national assessment of computer competence, conducted as a part of the National Assessment of Educational Progress (NAEP),[5] focused on those elements. During the 1985-86 school year, NAEP surveyed third-, seventh-, and eleventh-grade students on their knowledge and skills in using a computer, using questions dealing with recognition or recall of specific facts and

FIGURE 2

Sample Word Processing Questions

Put dough in a piy dish. Grese piy dish. ~~Open can of cherry piy filling~~ and pour it in piy dish. Bake at 350 degrees for 45 minutes and let cool.

"Pie" is spelled wrong four times. What is the best way to fix this problem?

- ● Search and Replace
- ○ Insert
- ○ Move (or Cut and Paste)
- ○ Delete

Percent Correct by Grade Level		
3	7	11
57.1	67.0	70.7

Put dough in a pie dish. Grese pie dish. Open can of cherry pie filling and pour it in pie dish. Bake at 350 degrees for 45 minutes and let cool.

The word "grease" is spelled wrong. What command is the best way to fix this one error?

- ○ Search and Replace
- ● Insert
- ○ Move (or Cut and Paste)
- ○ Delete

Percent Correct by Grade Level		
3	7	11
17.4	29.5	60.3

Put dough in a pie dish. Grease pie dish. Open can of cherry pie filling and pour it in pie dish. Bake at 350 degrees for 45 minutes and let cool.

The words "Grease pie dish" should go before "Put dough in a pie dish." What is the best way to fix this problem?

- ○ Search and Replace
- ○ Insert
- ● Move (or Cut and Paste)
- ○ Delete

Percent Correct by Grade Level		
3	7	11
27.6	48.4	67.1

FIGURE 3

Sample Database Questions

A class used a computer to store information about all 50 states in a database like the one below.

NAME OF STATE:
STATE BIRD:
STATE FLOWER:
DATE STATE BECAME PART OF THE UNITED STATES:

Can the class use the database to list all states that have red flowers?

○ Yes ● No

Percent Correct Grade 3: 42.1

Can the class use the database to list all states that have the daisy as their state flower?

● Yes ○ No

Percent Correct Grade 3: 58.2

A library has a computerized file of its books. A reader of science fiction wants to search the file and print a report like the one below. What would be the best procedure to follow?

Science Fiction Books Published after 1960

AUTHOR	TITLE	DATE
ASIMOV, ISAAC	TRIANGLE	1961
ASIMOV, ISAAC	FANTASTIC VOYAGE	1966
ASIMOV, ISAAC	THE FOUNDATION TRILOGY	1972
ASIMOV, ISAAC	THE GODS THEMSELVES	1974
CLARKE, ARTHUR C.	2001: A SPACE ODYSSEY	1968
CLARKE, ARTHUR C.	REPORT ON PLANET THREE	1972
CLARKE, ARTHUR C.	THE LOST WORLDS OF 2001	1972
CLARKE, ARTHUR C.	IMPERIAL EARTH	1976

Percent Correct by Grade Level	
7	11
23.5	28.8

- ○ *Sort by title and author, select year greater than 1960, print*
- ○ *Sort by author and title, select year less than 1960, print*
- ● *Sort by author and date, select year greater than 1960, print*
- ○ *Sort by author, select year less than 1960, sort by title, print*

ideas and procedures related to the use of computers (see figures 2-5). Although students did well on identifying parts of a computer, their overall performance on questions related to computer applications (word processing, graphics, databases, and spreadsheets) was much lower, as was their knowledge of programming (third- and seventh-graders were asked questions about LOGO and BASIC, and eleventh-graders, questions on BASIC and Pascal). Despite the emphasis on programming at this point in the "prevailing wisdom" continuum, students knew little about programming in the languages most commonly taught in schools at that time.

In their analysis, the authors of the NAEP report provided a framework for examining the differences in outcomes, especially those factors related to gender, race, and ethnicity; computer use in and outside school; and parental education. Although the analysis was made by region, type of community, and the experience of computer coordinators, a breakdown by socioeconomic status was not developed in this report, nor were there any data that provided insights on kinds of computer use by various populations of students.

The NAEP national assessment of computer competency has not yet been repeated, but in the 1994 student assessment in the areas of U.S. history, geography, reading, and mathematics, contextual information about computer use was collected from students, teachers, and administrators. Computer access and use data were not analyzed, however, against data that tracked the kinds of use against student achievement levels.

FIGURE 4

Sample BASIC Questions

You type these lines:

```
10 PRINT 5 * 7
20 PRINT 5 + 7
RUN
```

What does the computer print after you type **RUN***?*

○ Nothing

○ 5 * 7 / 5 + 7

● 35 / 12

○ 35 12

Percent Correct by Grade Level

3	7	11
9.1	24.0	34.4

You type these lines:

```
10 PRINT "MONDAY"
LIST
```

What does the computer print after you type **LIST***?*

○ Nothing

○ **MONDAY**

● 10 PRINT **"MONDAY"**

○ PRINT **"MONDAY"**

Percent Correct by Grade Level

3	7	11
35.9	41.1	44.7

Write a program in BASIC to print this:

```
COMPUTER
COMPUTER
COMPUTER
COMPUTER
COMPUTER
```

Percent Correct by Grade Level

	3	7
Incorrect	23.0	32.4
Partial	0.2	3.5
Correct	1.0	15.2
Omit	75.7	48.9

```
10 FOR X = 1 TO 5
20 PRINT "COMPUTER"
30 NEXT X
```

Note: This is one possible solution frequently offered by students.

FIGURE 5

Sample Specific Pascal Question

```
FUNCTION Get Value
(VAR A, B: integer): integer;
BEGIN  A : = A + 1;
       B : = B + 1;
       Get Value : = A + B
       END;
PROCEDURE Work(First, Second: integer);
CONST Stop = 10;
BEGIN        writeln(First);
             REPEAT
             writeln(Second)
             UNTIL Get Value(First, Second) > Stop
             END;
```

What would happen if the value of Stop were changed to 0 and the procedure call Work(5,7) were made?

○ **Get Value** would never be called.

● **Get Value** would only be called once.

○ **Get Value** would be called 12 times.

○ The loop would never stop.

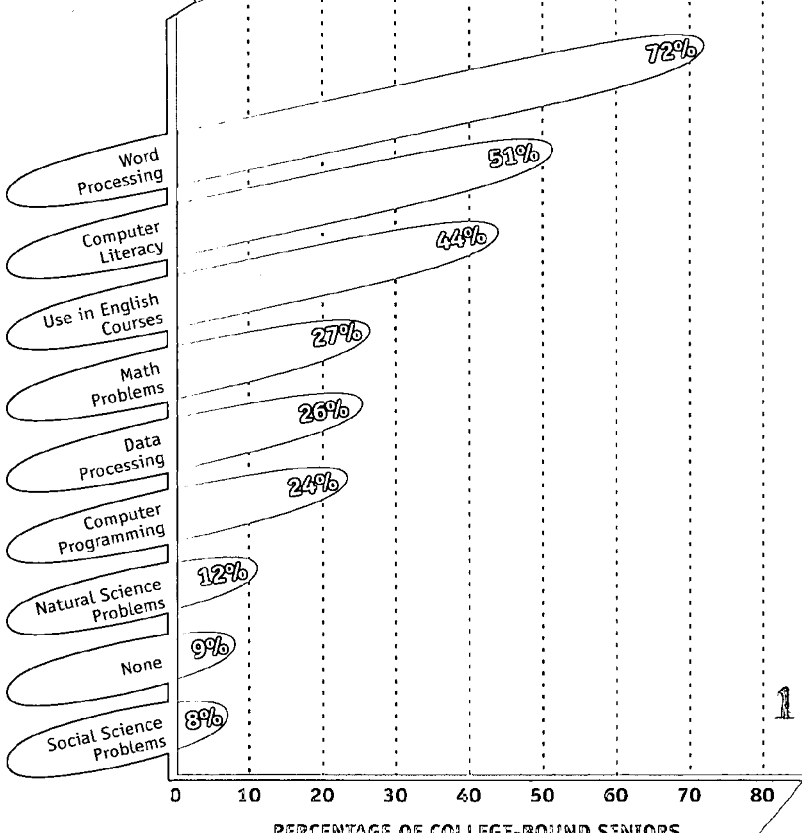
Percent Correct
Grade 11
28.3

Figures 2–5 Source: M.E. Martinez and N.A. Mead, "Computer Competence: The First National Assessment," Educational Testing Service, April, 1988.

Another national measure, again considering computer usage rather than skills, comes from recent data on course-taking patterns of college-bound seniors. More than one million students, the 1996 high school graduates who participated in the Scholastic Achievement Test (SAT) program during their high school years, provided information on the kinds of computer technology they used in the classroom in various areas, as well as changes over time.[6] In 1996, most students used the computer for word processing in English courses, followed by computer literacy. Only about one-quarter of respondents reported using computers for solving math problems, processing data, or programming their computers. Slightly more that one in ten used computers to solve problems in the natural sciences and even fewer, to solve problems in the social sciences. Nine percent reported no course work or experience in computer use, a drop from 26 percent in 1987. Although there were gains in word processing (from 36 to 72 percent) and in English courses (up from 12 percent in 1987 to 44 percent in 1996), there was a decline in programming over the decade (from 44 to 24 percent) and in the use of technology to solve math problems (30 percent reported in 1987 versus 27 percent in 1996). (See figure 6.)

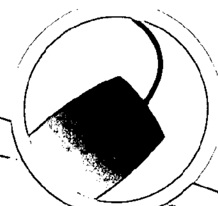
FIGURE 6

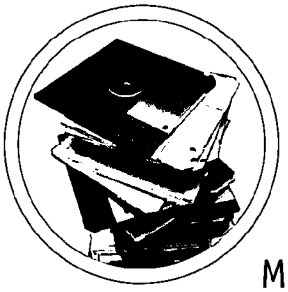
Percentage of College-Bound Seniors* Reporting Computer Use or Experience, 1996



* Who took the SAT

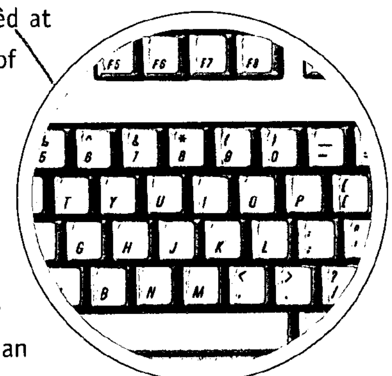
Source: College Board data published in R.J. Coley, J. Cradler and P.K. Engel, "Computers and Classrooms: The Status of Technology in U.S. Schools," Policy Information Report, Princeton, NJ, Policy Information Center, Educational Testing Service, May, 1997.





INTERNATIONAL ASSOCIATION FOR THE EVALUATION OF EDUCATIONAL ACHIEVEMENT

Measures of computer literacy, not unlike those in the first NAEP study, were targeted in the Computers in Education Study undertaken by the International Association for the Evaluation of Educational Achievement (IEA).[7] (Although a study in 1989 looked at computer access in 22 countries, not until the 1992 study was an attempt made to test and analyze basic computer knowledge and skills.) Twelve countries participated in the 1992 study, with test items developed and reviewed by an international team and translated into several languages. In the 1992 U.S. sample, 11,284 students in 573 schools were surveyed. As a part of the overall study, which also looked at computer equipment, teacher training, and out-of-school and in-school use of computers, students were tested on their practical computer knowledge. The curriculum analyses from the earlier study revealed that little consensus either within or across countries regarding computer goals, making it a challenge to design an assessment instrument. The instrument that was developed, called the Functional Information Technology Test, tested what students needed to function effectively with information-related tasks. The test items were built around concepts (e.g., "dialing a telephone number is an example of input"; "data are stored on a disk"), computer handling (e.g., "how to restart a computer after freezing"; "why is a backup copy on another diskette needed?"), and applications (e.g., "which program is suited for similar letters to several people?"; "interpretation of a spreadsheet screen").[8] Computer programming was not tested. In general, Western European students had the highest scores, followed by American students and Japanese students.

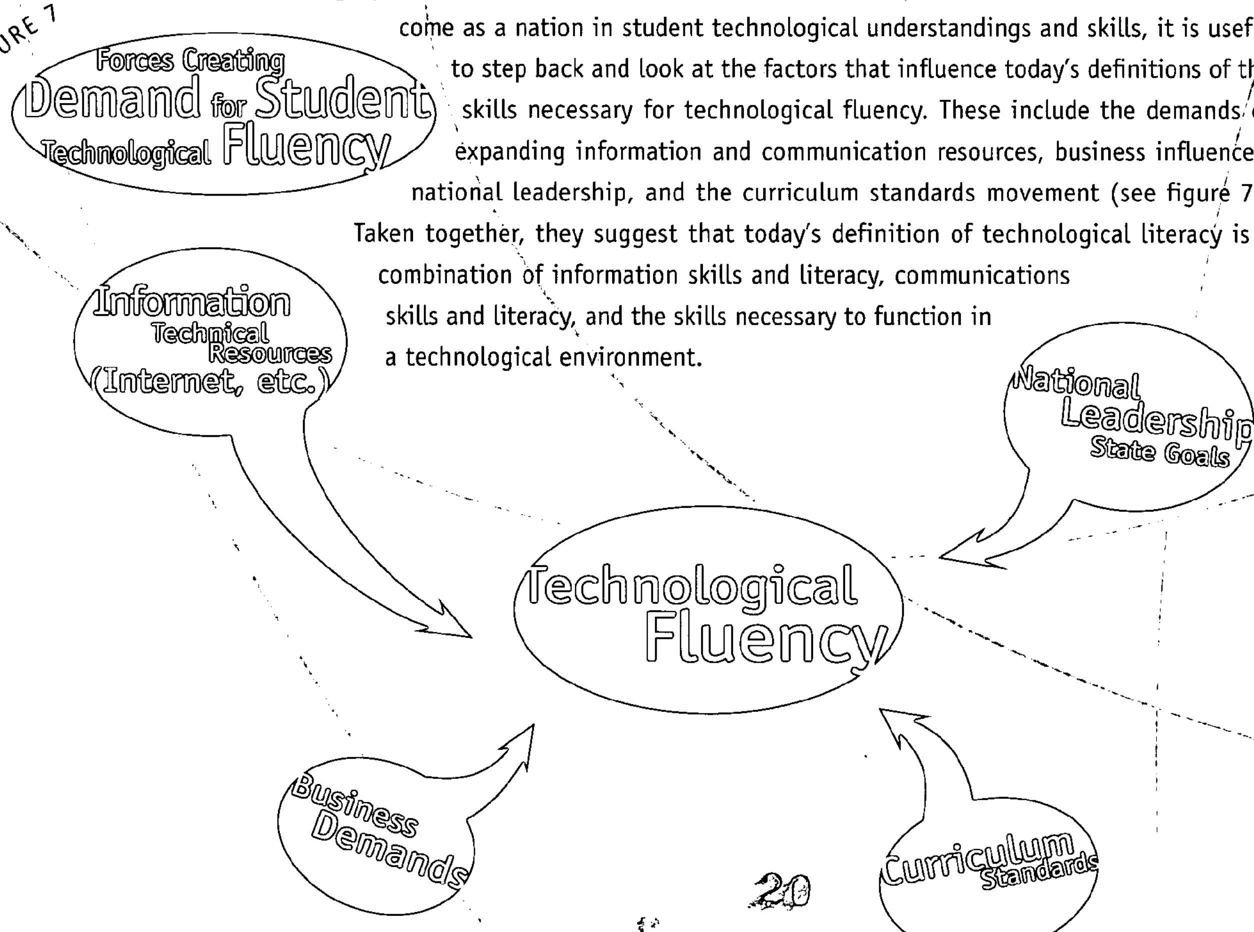


An analysis of the 1992 IEA study noted that, despite spending considerable time learning about computers, the United States did not give its students nearly as much formal or structured opportunities to learn practical computer knowledge as did Austria, Germany, and the Netherlands. Western European countries required computer-related classes (informatics) at the lower secondary level, but in the United States computer classes were more likely to be elective, not required. In comparing performance by ethnic groups in the United States, although ethnic minorities were more likely to report using computers and receiving instruction in computing in school, the achievement on practical computer knowledge of Native American, Hispanic, and African-American students was about 10 points lower than that of Asian and white students in both the eighth and the eleventh grades.

The IEA computer test has not been repeated, although another international assessment has been discussed, perhaps in the 2000–2001 school year. It is unclear, however, whether the National Science Foundation (NSF) will support U.S. participation, in part because of the difficulty of defining what should be tested and developing such instruments and appropriate test items. A smaller study, funded by NSF and the U.S. Department of Education, will be undertaken in the winter of 1997–98 to survey how U.S. teachers use technology in their teaching, whether for traditional forms of instruction or for more-constructivist, project-based learning activities. Although more limited in scope, this survey will provide the first national window on teachers' use of technology since the 1992 IEA study and could help us better understand how computers are used to support classroom instruction.[9]

Although past national and international assessments help us understand how far we have come as a nation in student technological understandings and skills, it is useful to step back and look at the factors that influence today's definitions of the skills necessary for technological fluency. These include the demands of expanding information and communication resources, business influences, national leadership, and the curriculum standards movement (see figure 7). Taken together, they suggest that today's definition of technological literacy is a combination of information skills and literacy, communications skills and literacy, and the skills necessary to function in a technological environment.

FIGURE 7

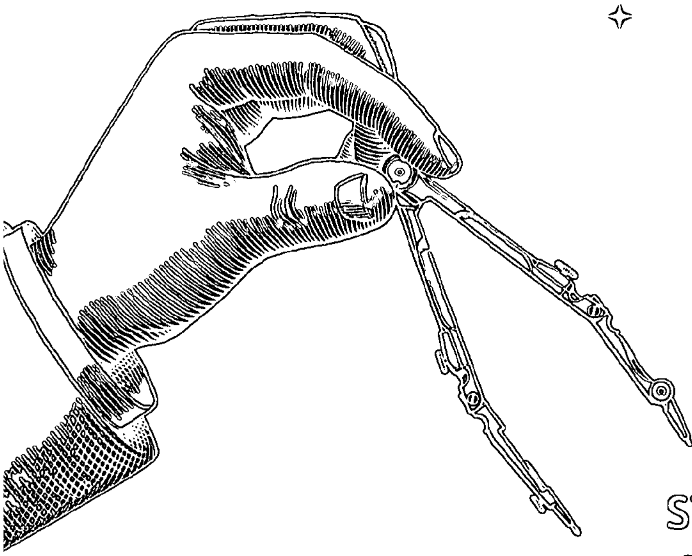


INFORMATION LITERACY IN THE AGE OF THE INTERNET

Concern about information literacy predates the computer age. In language arts, there has long been an emphasis on teaching students to analyze the written word and the messages found therein. With the influence of television in our daily lives, many have called for tools that help students interpret, critique, and evaluate what they see on television and in movies and videos. Today's rapid growth of the Internet and the access it provides to large amounts of information, however, have ignited a firestorm of concern regarding the need for information literacy. Unlike the information students received from earlier forms of media—textbooks, television, documentaries, library materials, all of which have been carefully researched, documented, and selected for publication and presentation, especially when used in educational settings—what comes across on the Internet is undigested information, provided alike by experts and novices, scholars and shysters, pedagogues and pedophiles. The days when teachers and parents were able to control and orchestrate all the information presented to students are gone. The technology of the Internet will force the development of broader information literacy skills for all students if we expect them to sort the wheat from the chaff, the true from the untrue, the rumor from the real. In order to work, learn, and flourish in what has been called the infosphere,[10] students will need to become skilled in

- Finding information from a variety of sources
- Evaluating information
- Making critical judgments about the information's value, reliability, and validity
- Creating and distributing information and knowledge via the many communication forms—text, video, graphics, conversation—that come together in today's technology-mediated communication formats

As noted in one state technology plan,

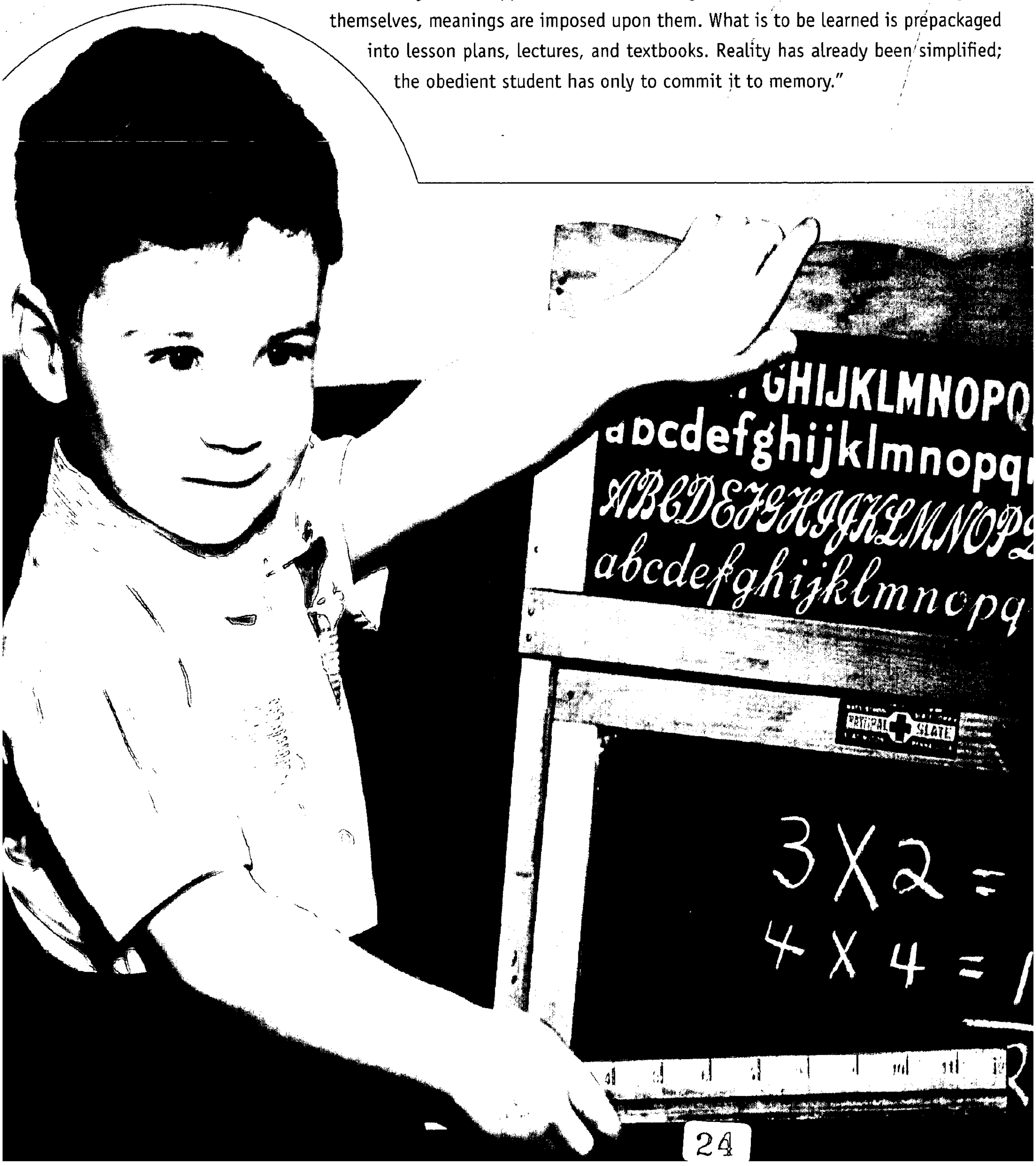


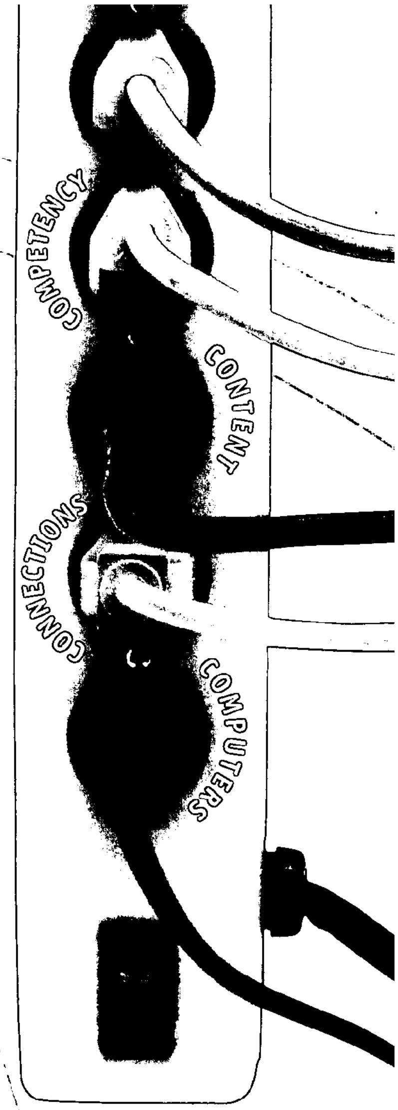
Just as 16th-century navigators were required to read the stars and understand tides to find their way, today's students must learn to become "information navigators," finding their way through print, graphic, electronic, and visual media to "discover" and interpret relevant information. They must become critical thinkers and analyzers using technology to access, interpret, and evaluate the quality and appropriateness of the information they have discovered. And, as navigators of old drew maps to share what they found with others, today's students must learn how to create and share knowledge using all the forms of media and telecommunications to communicate their ideas, engage in discourse, and solve problems.[11]

The Internet is just one of many technologies that will be central to the environment in which students will live and work.[12] Not surprisingly, the business community has been an important voice calling for students to develop technological literacy. As early as 1991, in the Department of Labor report *What Work Requires of Students*,[13] the Secretary's Commission on Achieving Necessary Skills (SCANS) identified the following as necessary for employment in the workplace:

- Resource allocation skills—handling time, money, materials, space, and staff
- Interpersonal skills—working on teams, teaching others, serving customers, leading, negotiating, and working well with people from culturally diverse backgrounds
- Information skills—acquiring and evaluating data, organizing and maintaining files, interpreting and communicating, and using computers to process information
- Systems skills—understanding social, organizational, and technological systems, monitoring and correcting performance, and designing or improving systems
- Technology skills—selecting equipment and tools, applying technology to specific tasks, and maintaining and troubleshooting technologies

As suggested by former Secretary of Labor Robert Reich and others, these skills are required in the expanding global economy in which American business must operate.[14] Success in this global economy requires high-performance industries that can create new products and high-quality services, or that add value to existing goods and services. In turn, these high-performance industries will be built around a workforce composed of flexible individuals who are able to change, adapt, and move with the opportunities technology and innovation offer. Management at all levels will require a cadre of "symbolic analysts," individuals who are competent in working with abstractions, facile with systems thinking, comfortable with experimentation, and able to work collaboratively to solve problems. In Reich's view, "The symbolic analyst wields equations, formulae, analogies, models, constructs, categories, and metaphors in order to create possibilities for reinterpreting, and then rearranging, the chaos of data that are already swirling around us."[15] He suggests that today's schools do not support this kind of learning: "For most children in the United States and around the world, formal education entails just the opposite kind of learning. Rather than construct meanings for themselves, meanings are imposed upon them. What is to be learned is prepackaged into lesson plans, lectures, and textbooks. Reality has already been simplified; the obedient student has only to commit it to memory."





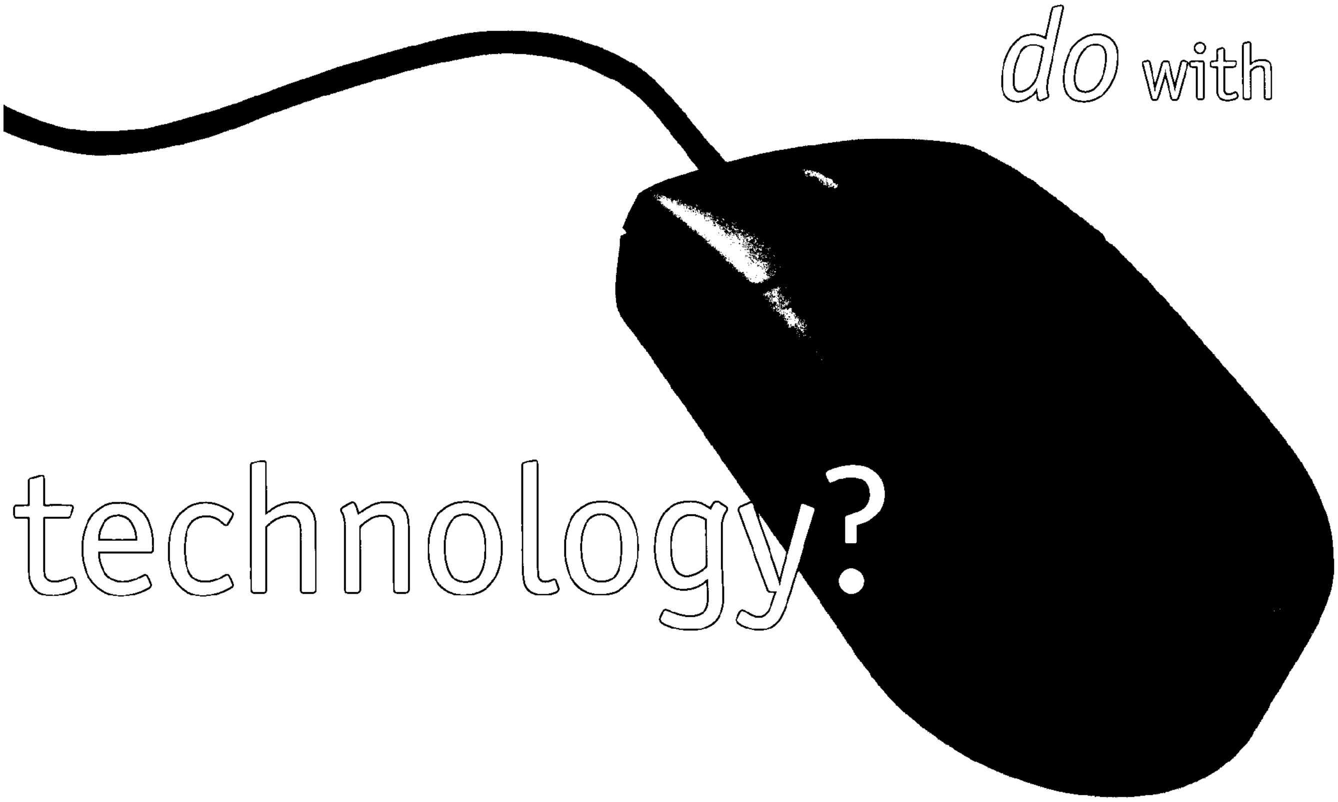
NEW VIEWS OF LEARNING

The SCANS report, Reich's analysis, and other wake-up calls from the business sector are supported by theories of learning that have developed over the last decade-and-a-half.[16] Schools during the last century were typically structured around a behaviorist learning theory in which teaching was telling and learning was memorizing. This transmission model fit the factory-like organization of schools of the industrial age.[17] New views of cognition support a constructivist view that does not dispute the importance of learning basic skills but holds that "advanced skills of comprehension, reasoning, composition, and experimentation are acquired not through the transmission of facts but through the learner's interaction with content."[18] This approach takes advantage of a student's natural ability to learn through experience and to "create mental structures which organize and synthesize the information and experiences which the individual encounters in the world."[19] Information and communication technologies such as the Internet support this approach to teaching and learning, which encourages learning in authentic contexts, collaboration and external supports, and use of multiple primary source materials and resources as well as textbooks.

FEDERAL LEADERSHIP AND NATIONAL STANDARDS

Federal leadership, from the identification of computer literacy as a fourth basic skill in *A Nation at Risk* in 1983 to the current emphasis on educational technology in the Clinton administration, has brought important attention and resources to the picture.[20] The current Technology Literacy Challenge Initiative is built around four pillars—computers, connections, content, and competency—but there is less clarity in defining how students should use these tools and what might be considered technological literacy as a result of investments in these areas.[21] Because the United States, unlike many other countries, does not have a national curriculum, this is not surprising. However,

what exactly
should a
person
know about
and
be able to
do with



technology?

an emerging consensus on what students should learn, building on the national curriculum standards, has been developed over the last several years by a range of professional associations. Those standards have helped develop curriculum standards and benchmarks (some are now being drafted) at the state and district level in the areas of mathematics, science, history, language arts, geography, the arts, civics, economics, foreign languages, health, physical education, and social studies.[22] Such standards vary in scope, level of detail, and format, as well as in how clearly technological skills are identified within the content and competencies they propose.

A strong force in standards-based reform is the New Standards Project, begun in 1991, by the National Center for Education and the Economy (http://www.ncee.org). With substantial support from philanthropic foundations, this voluntary coalition of states and local school districts was created to conduct research, produce assessment instruments, and establish professional development models to improve teaching and learning in core academic subjects throughout American schools.[23] Performance standards extend across all school levels and are available in English language arts, mathematics, science, and applied learning. These standards build on the consensus content standards developed by the national professional associations noted above. They also include "New Standards Reference Examinations" designed to measure student achievement in mathematics and English language arts, using a mix of traditional text items and performance tasks that call upon students to solve complex problems. Computer skills are not distinguished as discrete standards, but are embedded in content standards and applied learning skills. The New York City Board of Education has adopted these standards for all New York City public schools.

Two sets of frameworks under development by professional associations directly focus on technology education and information literacy. The "technology literacy" standards were proposed by the International Technology Education Association (ITEA); the "information literacy" standards were prepared by the Association of American School Librarians and the Association of Educational Communications and Technology.

ITEA Standards The ITEA, with funding from the National Science Foundation and the National Aeronautics and Space Administration, created the Technology for All Americans Project, which aims to develop standards for K–12 technology education. The framework seeks to address "What experiences, abilities, and knowledge are needed for technological literacy? What exactly should a person know about and be able to do with technology? What should be the content of this literacy effort?" In Phase I of the project, a 25-member national commission created the consensus document *Technology for All Americans: A Rationale and Structure* *for the Study of Technology* in 1995–96.[24] Phase II, scheduled for October, 1996, through September, 1999, will develop K–12 content standards with benchmarks at second, fifth, eighth, and twelfth grades. The focus is technology as a *subject* as opposed to a *vehicle* for learning other subjects. The first draft, which was developed in October, 1996, and is now being reviewed nationally, is composed of two frameworks: knowledge of technology ("what every child should be able to *know*") and processes with technology ("what every child should be able to *do*"). Technology is considered across three macrosystems: information technology, physical technology, and biotechnology.

Association of American School Librarians/Association for Educational Communications and Technology Standards Information literacy is the focus of the standards being developed by the Association of American School Librarians (AASL) and the Association for Educational Communications and Technology (AECT).[25] Although their guidelines are aimed at school library media programs and professionals, they have been correlated to learning concepts developed under other national association standards. The draft for these standards, which is still under review, has three main categories, nine standards, and 29 indicators that correspond to information-age skills needed for twenty-first-century success. The first category, called *information literacy*, is the area where school library media programs have the most direct responsibility. This category includes the standards "access information efficiently and effectively" and "evaluates information critically and competently," skills important for all areas of the curriculum. The second category, *independent learning*, calls for the learner who "pursues information related to personal interests"; "appreciates and enjoys literature and other creative expressions of information"; and "strives for excellence in information-seeking and knowledge-generation." These characteristics, key to one who is prepared for lifelong learning, echo the words of the president of Smith College, who welcomed an entering freshman class with the words, "The goal of a liberal arts education should be to make your mind an interesting place in which to spend the rest of your life."[26] The third category, *social responsibility*, seeks to ensure that our schools produce the citizens necessary to support and maintain a free and productive society, with learners who "recognize the importance of information to a democratic society" and "participate effectively in groups to pursue and generate information."

State and District Technology Skill Standards and Assessments

Although the national standards for curriculum and content provide useful guidance, policymakers at the state and district levels continue to struggle with whether they should define and measure learning goals *for* technology (what I call first-level technology skills) or define and measure learning *through* technology (second-level technology skills). Like most educational activities in this country, there is considerable variation across states, districts, and schools in curriculum, assessment, and daily programs. Defining and assessing standards for developing student technological skills and use covers a wide range: in some cases, in a special computer curriculum, in others, embedded within the learning goals in other content areas. Given below is the flavor of this variation. Although by no means an exhaustive survey, it does provide a snapshot of approaches being tried in some states and districts.

SELECTED STATE APPROACHES TO TECHNOLOGY STANDARDS

According to state technology directors responding to an informal survey conducted by the Office of Educational Technology at the U.S. Department of Education, student technology standards are typically embedded in state curriculum guides.[27] Twenty states reported embedded standards; only eight states reported separate technology standards at the state level. Examples of both approaches are given below.

North Carolina North Carolina has developed a computer skills curriculum, with objectives and performance outcomes defined for each grade level (see figure 8).[28] The stakes are high: Beginning with the class of 2000, mastery of computer proficiencies will be a requirement for graduation. The knowledge component and demonstration assessment will be administered in the eighth grade. The competency goals and tasks are grade-level specific, with many supported by lesson plans, resource materials, and suggested software. Competencies are also required for educators (see "Implications for Policy" beginning on page 45).

continued on page 32

Public Schools of North Carolina

FIGURE 8

Computer Skills Curriculum

Glossary

COMPETENCY GOAL 1:

The learner will understand important issues of a technology-based society and will exhibit ethical behavior in the use of computer technology.

1.1 Identify the ways technology has changed the lives of people in communities.

1.1.1 Draw a "before" and an "after" picture of a way technology has changed a community. Write a short description of each illustration.

1.2 Explain that the copyright law protects what a person or a company has created and placed on a diskette.

1.2.1 Tell why it is against the law to make a copy of a copyrighted software program to give to a friend.

1.2.2 Role-play situations that involve illegal copying of another person's computer work or software. Discuss why copying or receiving such software is wrong.

COMPETENCY GOAL 2:

The learner will demonstrate knowledge and skills in using computer technology.

2.1 Identify the physical components of a computer system as either input, output, or processing devices.

2.1.1 Label pictures of a computer keyboard, disk drive, monitor, printer, mouse, and CPU as input, output, or processing devices.

2.2 Demonstrate proper keyboarding techniques for keying all letters.

2.2.1 Using a keyboarding device or computer, show the proper technique to type each key as it is called out by the teacher.

Resources: *Key It Correctly!* Lesson Plan

2.2.2 Given keyboarding software or a keyboarding device, use home-row keyboarding techniques to type appropriate vocabulary words.

Resources: *Key Vocabulary Words!* Lesson Plans

Grade Level Three

2.3 Use a word-processing program to load, enter, save, and print text.

2.3.1 Given a story-starter file, load the file into your computer and type sentences that complete the story. Save and print the story.

Resources: *Get in the Green* Lesson Plan

2.3.2 After loading a class journal file into your computer, enter a brief summary of today's activities and save the journal file for the next day.

Resources: *Halloween Tales* Lesson Plan

2.4 Use commercial software in content areas.

2.4.1 Use computer programs to practice multiplication skills.

2.4.2 Use computer programs to reinforce concepts of prefixes and suffixes.

2.5 Demonstrate correct use of hardware and software.

2.5.1 Make up a skit that demonstrates the correct and incorrect operation and handling of hardware and software.

Competency Goal 2: General Additional Resources

KID'S STUDIO from Spring 1995 Media Advisory List
FLYING COLORS from Winter 1994 Media Advisory List
CLICK D. MOUSE HYPERCARD CONSTRUCTION SET from Fall 1994 Media Advisory List
HYPERSTUDIO from Summer 1994 Media Advisory List

COMPETENCY GOAL 1:

The learner will understand important issues of a technology-based society and will exhibit ethical behavior in the use of computer technology.

1.1 Identify technological skills required for various careers.

1.1.1 Assume the role of "boss" in a business or professional firm. List technological skills necessary for workers in the firm.

1.2 Distinguish between different types of data as to which are public and which are private.

1.2.1 Given a list of several types of information, categorize which should/should not be readily available to others in a database (e.g., name, age, height, weight, favorite color, number of siblings, favorite music group, preferred pizza topping).

1.2.2 Word process a letter to the editor of the school newspaper on why student test scores, attendance, or detention/suspension records should be private data.

1.3 State the need for protection of software and hardware from computer viruses.

1.3.1 Find articles about computer viruses in newspapers or in a print/electronic magazine index. Report findings to the class. Discuss ways of protecting against such viruses.

1.3.2 Working in a group, chart and report the possible effects of computer viruses on at least two of the following: schools, businesses, health services, scientific research, or national defense.

COMPETENCY GOAL 2:

The learner will demonstrate knowledge and skills in using computer technology.

2.1 Revise word-processed text to be a simple desktop published document.

2.1.1 Given a word-processed file, change titles and selected text to bold style.

Resources: *North Carolina and the American Revolution (Lesson 1)* Lesson Plan

2.1.2 Given a word-processed file and a collection of clip art, rearrange the text to "paste" the clip art selections, either by computer or by paper and tape/glue.

Resources: *North Carolina and the American Revolution (Lesson 2)* Lesson Plan

Competency Goal 2: General Additional Resources

Spring 1995 Media Advisory List
HOW MULTIMEDIA COMPUTERS WORK

Grade Level Eight

Winter 1994 Media Advisory List
FLYING COLORS
VIRTUS VR
FAMILY TREE MAKER VERSION 2.0 DELUXE CD-ROM EDITION

Summer 1994 Media Advisory List
HYPERSTUDIO

COMPETENCY GOAL 3:

The learner will use a variety of computer technologies to access, analyze, interpret, synthesize, apply and communicate information.

3.1 Given a prepared database, use sorting and searching techniques to solve a specific problem.

3.1.1 Given a database of the counties of North Carolina, identify counties in the coastal region that would be desirable for opening a pediatric clinic.

Resources: *NC County Hunters, Inc.* Lesson Plan

3.1.2 Given a database of the counties of North Carolina, identify counties in the mountain region that would be preferable for retirement.

Resources: *NC County Hunters, Inc.* Lesson Plan

3.2 Enter and edit data into a prepared spreadsheet to test "What if?" statements.

3.2.1 Given a prepared spreadsheet with the relative gravity of each planet, determine the weight of five objects on each planet.

Resources: *Astronomy Mission* Lesson Plan

3.2.2 Given a prepared spreadsheet on the income from shrimping in North Carolina, test "What if?" scenarios by entering possible amounts of pollutants dumped into the water, and observing the resulting effects on shrimp harvests.

Resources: *SOS: Save our Shrimping Industry* Lesson Plan

Competency Goal 3: General Additional Resources

Spring 1995 Media Advisory List
mPOWER

Winter 1994 Media Advisory List
VIRTUS VR
EXEGY
FAMILY TREE MAKER VERSION 2.0 DELUXE CD-ROM EDITION

Summer 1994 Media Advisory List
HYPERSTUDIO
MEDIASOURCE: HISTORICAL LIBRARY—VOLUME 1

FIGURE 9

Educational Technology Skills

APPLICATIONS/PROGRAMMING	K	1	2	3	4	5	6	7	8	9-12
Keyboarding/Data Entry	○	○	○	○	▲	▲	◆	●	■	■
Word Processing		○	○	○	▲	▲	◆	◆	●	■
Problem Solving Simulation	○	▲	▲	▲	▲	▲	▲	▲	▲	▲
Spreadsheet				○	○	○	▲	▲	◆	■●
Database						○	○	▲	▲	■●
Graphics	○	○	○	▲	◆	◆	◆	●	●	■
Desktop Publishing	○	○	○	○	▲	▲	▲	◆	◆	■●
Multimedia/Presentation				○	○	▲	▲	◆	◆	■●
Electronic Portfolio						○	▲	◆	◆	■●
E-Mail		○	○	▲	◆	◆	▲	▲	●	■
Conferencing/Chat Group						○	▲	▲	◆	■●
Video Teleconferencing								○	▲	◆●
Languages				○	▲	▲	▲	▲	▲	◆▲

RELATED SKILLS	K	1	2	3	4	5	6	7	8	9-12
Care & Maintenance	○	▲	▲	▲	◆	◆	◆	◆	◆	■
Select Tool for Task	○	▲	▲	▲	◆	◆	◆	◆	◆	■
Mouse Pointer Skills	○	▲	◆	◆	◆	◆	◆	◆	◆	◆
Use Help Menu				○	○	○	▲	◆	●	■
File Management			○	○	○	○	▲	◆	●	■
Program Execution	○	○	○	○	○	○	▲	◆	●	■

TECHNOLOGY RESPONSIBILITIES	K	1	2	3	4	5	6	7	8	9-12
Ethical Behaviors	○	▲	▲	▲	◆	◆	◆	◆	◆	◆
Copyright Laws				○	▲	▲	◆	◆	◆	◆
Internet Consumer Awareness				○	▲	▲	◆	◆	◆	◆
On-Line Etiquette				○	▲	▲	◆	◆	◆	◆
Virus Protection				○	▲	▲	◆	◆	◆	◆

DATABASE SEARCH	K	1	2	3	4	5	6	7	8	9-12
On-line Library Catalog		○	○	▲	◆	◆	◆	◆	◆	◆
CD-ROM		○	○	○	▲	◆	◆	◆	◆	◆
Internet					○	▲	◆	◆	◆	●■

RELATED CONCEPTS	K	1	2	3	4	5	6	7	8	9-12
Careers in Technology	○	▲	▲	▲	▲	▲	▲	▲	▲	▲
Technology Terminology	○	○	▲	▲	▲	▲	▲	▲	▲	▲
Social/Economic Impact					○	○	○	▲	▲	▲

COOPERATIVE LEARNING	K	1	2	3	4	5	6	7	8	9-12
Cross Curricular/Grade	○	▲	▲	▲	▲	▲	▲	▲	▲	▲
Group Decision Making			○	▲	▲	▲	▲	▲	▲	▲
Peer Teaching							○	▲	▲	▲

◎ Expose to Skill or Behavior
△ Focus Instruction on Skill or Behavior
◇ Apply Basic Skill
○ Master Basic Skill
□ Maintain/Enrich (Advanced Applications)

Source: B. Shriver, "K–12 Educational Technology and Business Standards," DoDEA, Arlington, VA, August, 1997.

Department of Defense Education Authority The Department of Defense Education Authority (DoDEA) serves as the equivalent of a state department of education in schools for military dependents around the world.[29] The DoDEA's approach is similar to North Carolina's in its grade-level specificity of technology skills. A set of strategic skills for student learning, including technology skills, has been created for the K–6 level, and high school standards are under development. The K–6 technology skills are grade-level and topic specific and include applications and programming, technology responsibilities, database searches, and cooperative learning (see figure 9). Following a teacher assessment, student proficiencies in technology skills will be developed, currently part of their planning for the 1999–2000 school year. The goal is to conduct the assessment with a portfolio demonstrating competencies.[30]

Texas As early as 1984, Texas defined computer literacy and built a curriculum guide and course materials to support the integration of computer skills within the Texas essential knowledge and skills framework.[31] In the spring of 1992, the state board of education approved the creation of a computer-based technology-assessment designed to determine the computer proficiency of middle school students. It was to be administered solely on the computer, with machine scoring offering immediate feedback to the student and diagnostic feedback to the teacher. The three domains to be tested were foundation concepts (understanding the relationships of technology components, basic functional software packages and the application of these packages, and problems and issues in using technology

SKILLS: NETWORKING TECHNOLOGIES	K	1	2	3	4	5	6	7	8	9-12
Accessing LAN	○	○	○	▲	▲	▲	▲	◆	◆	●■
Accessing WAN					○	▲	▲	◆	◆	●■
Networking									○	▲◆

in society); applications (word processing, database, and spreadsheet use); and problem solving. Although these concepts continue to be taught, and a draft of the assessment was developed and distributed to districts in the spring of 1995 as a guideline for technology integration, the statewide testing was canceled by the legislature. Instead, only foundation areas (e.g., math, language arts) were included in the statewide testing program. The Texas Education Authority is exploring the possibility of making the computer-based technology assessment instrument available to districts for local use.

SKILLS: SPECIALIZED TECHNOLOGIES	K	1	2	3	4	5	6	7	8	9-12
Animation					○	◆	◆	●	■	■
CADD								○	▲	◆■
CAMM/CNC/CIM								○	▲	◆
Analog/Digital Production								○	▲	◆
Energy/Power Systems								○	▲	◆
Hydraulic/Pneumatics								○	▲	◆
Lasers								○	▲	◆
Mechanical Systems								○	▲	◆
Robotics								○	▲	◆
Sensors								○	▲	◆
Virtual Reality								○	▲	◆
MIDI								○	▲	◆

California As a result of recommendations made by the California Education Technology Task Force in its 1996 report *Connect, Compute, and Compete,*[32] California is developing technology-based content and performance standards for students, as well as for their teachers. The draft report provided by the Education Council for Technology in Learning recommended to the state board that technology standards should be incorporated into the core content academic and performance standards being developed for state approval.[33] Believing that young children exposed to technology may well possess skills and knowledge far beyond those of their high school or even college counterparts, the California plan does not correlate technology knowledge and proficiency with specific grade levels. Instead, three levels of student proficiency standards have been identified: threshold, basic, and advanced. Each level is defined with objectives, followed by performance standards. No testing per se is defined, but the performance standards require that the student demonstrate the ability to use, access, develop, prepare, evaluate, and perform appropriate functions related to these levels. Rather than align these standards to content requirements in any academic field, the council has recommended that this alignment be undertaken with grade progression and graduation requirements being developed for state board approval.

FIGURE 10

English – Reading

Common Curriculum Goals	Content Standards	Grade 3 Benchmark	Grade 5 Benchmark	Grade 8 Benchmark	CIM/Grade 10 Benchmark	AASL/AECT National Standards
Connect reading selections to other texts, experiences, issues and events.	Select and use a variety of information resources to draw connections and explain relationships between reading selections and other texts, experiences, issues and events.	Use information resources to connect reading selections to other texts, experiences, issues and events.	Use information resources to connect reading selections to other texts, experiences, issues and events.	Use information resources to connect reading selections to other texts, experiences, issues and events.	Use information resources to connect reading selections to other texts, experiences, issues and events.	Pursues information related to personal interests... 1. seeks information related to various dimensions of personal well-being, such as career interests, community involvement, health matters, and recreational pursuits. 2. designs, develops, and evaluates information products and solutions related to personal interests.

English – Literature

Common Curriculum Goals	Content Standards	Grade 3 Benchmark	Grade 5 Benchmark	Grade 8 Benchmark	CIM/Grade 10 Benchmark	AASL/AECT National Standards
Read a variety of literary forms (e.g., novels, poems, plays, short stories, autobiographies, essays) of varying complexity from a variety of cultures and time periods.	Read selections from a variety of cultures and time periods and recognize distinguishing characteristics of various literary forms.	Read and identify stories, poems, plays and nonfiction from a variety of cultures and time periods.	Read and identify literary forms, including novels, short stories, poetry, plays and nonfiction from a variety of cultures and time periods.	Read and identify distinguishing characteristics of a variety of literary forms, including novels, short stories, poetry, plays and nonfiction from a variety of cultures and time periods.	Read and identify distinguishing characteristics of a variety of literary forms, including novels, short stories, poetry, plays and nonfiction from a variety of cultures and time periods.	Recognizes the importance of information to a democratic society... 1. seeks information from diverse sources, contexts, disciplines, and cultures. 2. respects the principle of equitable access to information.

English – Writing

Common Curriculum Goals	Content Standards	Grade 3 Benchmark	Grade 5 Benchmark	Grade 8 Benchmark	CIM/Grade 10 Benchmark	AASL/AECT National Standards
Use a variety of written forms (e.g., journals, essays, short stories, poems, research papers, business communications, and technical writing) to express ideas and multiple media to create projects, presentations, and publications.	Select and use a variety of media and instructional technology resources to support student-created products.	Use information resources to support ideas expressed in a variety of written forms.	Use information resources to support ideas expressed in a variety of written forms.	Use information resources to support ideas expressed in a variety of written forms.	Use information resources to support ideas expressed in a variety of written forms.	Strives for excellence in information-seeking and knowledge-generation... 1. assesses the quality of the process and products of one's own information-seeking.

Source: Oregon Information Literacy Guidelines, Oregon Educational Media Association, Sheryl Steinke, Chair. Draft February, 1997.

Oregon Technology standards in Oregon, built around the information literacy guidelines developed by the Oregon Educational Media Association,[34] have two parts, one of which is more developed than the other. Part One, the section of media technology, reading, writing, and literature, is complete, with curriculum goals, content standards, and benchmarks developed for grades three, five, eight, and ten in each topic area (see figure 10). Part Two, Information literacy through specific curricular areas (science: scientific inquiry and science in personal and social perspectives; social sciences: social science analysis, geography, and civics; health education; and art), is still being developed. Each standard has been correlated with AASL and AECT national standards.

Illinois Curriculum standards recently approved by the Illinois State Board of Education integrate technology skills and their assessment throughout the subject areas, rather than as a separate curricular area. The board has adopted a rich definition of technology: "the combination of human imagination, inventiveness, and the electronic/optical tools to transform ideas into reality."[35] Standards for technology are embedded in the benchmarks for the curriculum standards rather than as a separate set of competencies. Neither technology-specific nor grade-level-specific benchmarks, they are built around "six essential learnings in a technological society" (see figure 11).[36] The indicators call for assuring that all students are

- Information seekers, navigators, and evaluators
- Critical thinkers, analyzers, and selectors of information and technologies appropriate to the task
- Creators of knowledge using information resources and technology
- Effective communicators using a variety of appropriate technologies/media
- Technical users
- Responsible citizens in a technological age

FIGURE 11

Six Essential Learnings in a Technological Society

Technology is defined to be the combination of human imagination, inventiveness and the electronic/optical tools to transform ideas into reality. Effective use of information and technology will require students to develop new roles in living, learning and working in an increasingly complex and information-rich society. The following essential learnings for technology are fundamental to the work of the Illinois State Board of Education as it develops content standards, performance standards, and assessments for all academic areas.

1. The student as information seeker, navigator and evaluator. The student recognizes and values the breadth of information sources, browses those sources, differentiates and selectively chooses sources based on soundness and relevancy, and retrieves appropriate information/data using all forms of electronic/optical media, technology and telecommunications.

2. The student as critical thinker, analyzer and selector of information and technologies appropriate to the task. The student uses problem-solving techniques and technology tools to review information and data from a variety of sources; analyzes, synthesizes and evaluates it; and then transforms the myriad of ideas, data and information into useful information and knowledge. During this process the student discriminates among a variety of technologies and electronic/optical media to extend and expand his/her capabilities.

SELECTED DISTRICT APPROACHES

School districts, like states, vary in the approaches they take to technology skills development and assessment. Two contrasting approaches are given below: one emphasizing specific skills (Jefferson County) and one building around technology embedded in other classroom processes (Cupertino Union School District).

Jefferson County Public Schools One of the largest and most extensive technology skills curriculum and assessment system created by a school district is the Computer Applications Skills Continuum currently being developed by the Jefferson County Public Schools in Louisville, Kentucky.[37] The 20th-largest school district in the nation, with more than 90,000 students, Jefferson County has invested heavily in technology and has long been considered a leader in computer technology. Nevertheless, when a new superintendent came in three years ago and asked, "What can the kids do with the technology?" the answer, "Lots of fabulous things," wasn't enough for him. He challenged the district to "prove it," and the technology support personnel in the county set to work. They looked around for what other districts might be doing to test their students' computer skills and, finding nothing that met their needs, in 1994, began developing their own assessment tool as part of a five-year technology plan. Considering computer technology as both a "tool for learning" and a "tool to be learned," they developed four categories for testing across the K–12 continuum: keyboarding, word-processing, database, and spreadsheet skills. (Telecommunications/information retrieval and

3 The student as creator of knowledge using information resources and technology. The student, both individually and as a successful member of a team, constructs new meaning and knowledge in all content areas, combining and synthesizing different types of information through technology, telecommunications and computer modeling/simulations.

4 The student as effective communicator using a variety of appropriate technologies/media. The student creates, produces and presents ideas, stories and unique representations of thoughts through a variety of electronic/optical media by analyzing the task before him/her and the technology tools available, appropriately selecting and using the most effective tool(s)/media for the purpose and audience.

5 The student as a technical user. The student develops the confidence, competence, information management strategies and sufficient technical skills to successfully install, setup and use the technology and telecommunications tools in his/her daily life, work situations and learning environments.

6 The student as a responsible citizen in a technological age. The student understands the ethical, cultural, environmental and societal implications of technology and telecommunications and develops a sense of stewardship and individual responsibility regarding his/her use of technology, media and telecommunications networks.

Source: Illinois State Board of Education, "K-12 Information Technology Plan," Springfield, IL, 1996, pg. 28.

ethical and legal issues were added in 1997, but students have not yet been tested in the category of telecommunications and information retrieval skills since not enough classrooms have regular access to the Internet.) The emphasis varies with the grade level, and mastery of prior skills provides the base for continued growth (see figure 12).

FIGURE 12

Jefferson County Public Schools

Computer Applications Skills Continuum
PRIMARY 4

KEYBOARDING	WORD PROCESSING	DATABASE	SPREADSHEET	TELECOMMUNICATIONS/ INFORMATION RETRIEVAL	ETHICS AND LEGAL ISSUES
Keyboard with suggested speed of 10 wpm Reinforce and expand skills introduced at preceding levels	Demonstrate how to place cursor Use tab key to indent paragraph Print documents Leave blank line between heading and rest of document Reinforce and expand skills introduced at preceding levels	Search for specific information Answer questions using database Reinforce and expand skills intro-duced at preceding levels	Save, print and retrieve spreadsheet documents Reinforce and expand skills introduced at preceding levels	Identify community resources that use telecommunications equipment in everyday activities Reinforce and expand skills introduced at preceding levels	Recognize that reference materials must be put in own words or cited Understand and respect the following laws regarding software use: Public Domain-software that can be freely copied and distributed Shareware- software that can be copied and shared, but any user of the software is obligated to pay a fee to the author Commercial software-software that is produced and sold by a company for profit with one backup copy allowed by publisher as described in software documentation Use language that does not include profanity, socially sensitive remarks or insults Reinforce and expand skills introduced at preceding levels

KEYBOARDING	WORD PROCESSING	DATABASE	SPREADSHEET	TELECOMMUNICATIONS/ INFORMATION RETRIEVAL	ETHICS AND LEGAL ISSUES
Use two hands while keyboarding with suggested speed of 25 wpm Create and use macros Reinforce and expand skills introduced at preceding levels	Insert/import graphics Adjust margins Create graphics and use graphics tools Reinforce and expand skills introduced at preceding levels	Place headers Incorporate graphics and/or use draw tools on the database Reinforce and expand skills introduced at preceding levels	Change cell dimensions Change fonts/size of data in cell Change alignment of cell data Reinforce and expand skills introduced at preceding levels	Reinforce and expand skills introduced at preceding levels	Reinforce and expand skills introduced at preceding levels

Source: Jefferson County Public Schools Educational Technology Department, Louisville, KY.

For example, in the 1998 plan for first grade, only keyboarding is addressed, but in second grade an introduction to each area (except telecommunications) is required. The specific skill is matched to what the children are learning in the curriculum (e.g., in second grade, the use of periods and questions marks at the end of sentences is listed as a word-processing skill, as is using capital letters when appropriate). For keyboarding, target speeds are suggested starting in the fourth grade (10 words per minute (wpm), moving to 15 wpm in fifth grade and so forth, up to 45 wpm in twelfth grade). Although the plan has what may be considered arbitrary guidelines (e.g., the numerical keypad is given as a sixth-grade skill), it gives teachers a clear sense of what they should be doing with students at various levels. The fact that, in the normal course of events, many of the sixth-grade activities may indeed be mastered by children in the course of their computer activities in earlier grades could be considered a plus if these competencies are seen as basic fundamental skills.

The tests are given to a random sample of 9,000 students, at grades three, five, eight, and ten, with an annual review of the assessment instrument. The tests have both a paper and pencil and a computer-based component. The first year of testing confirmed what many had suggested but had not yet been validated—that is, that although elementary students did well (most scoring at the 95 or 100 percent proficiency level), there was a greater variation in test results as grade levels increased. Thus, the eighth-grade students had somewhat mixed results, but at the high school level there was a huge dichotomy of scores, with some students scoring at the 0 mastery level and others at 100 percent mastery. Those findings led to a greater investment in and distribution of computers for middle and high schools and ensuring that all high school students participate in computer courses of some kind. In the second year of testing, 100 percent of the tested students scored at least the 80 percent mastery level across the K–12 spectrum.

The superintendent would like to see all the Jefferson County Public Schools tested, not just the current 10 percent random sample, but this creates huge logistical challenges (for example, making sure there are enough working computers in all schools to test such large numbers of students at once). There are also public relations concerns if testing results are reported school by school. In 1998, as many as 75 percent of, and perhaps all, elementary students will be tested, but middle and high school testing will continue to be small, at least for the time being. Furthermore, in keeping with the state's interest in portfolios and authentic assessment, greater use will be made of such test items as "demonstrations of quality work (DQW)." Piloted at the middle school testing this year, this portion of the assessment gives a student an hour-and-a-half to solve a problem using word processing, a database, and a spreadsheet. The DQW items are being scored at the district level, and the results are not yet available.

Demonstrations of Quality Work

Cupertino Union School District This district's Technology Scope and Sequence was developed around three educational processes already occurring in the classroom: (1) gathering information, (2) organizing information, and (3) composing and publishing.[38] Believing that most curricular/content areas contain aspects of these three functions, Scope and Sequence directs teachers on how to integrate technology into the curriculum around them. Each section of Scope and Sequence contains recommended activities, technology-specific skills, possible applications (hardware and software), and examples of curricular-related activities, as students progress through several levels of proficiency. Testing of these skills is not specified, although a student's movement along the continuum would indicate mastery of the prior level. The guide is independent of grade level (see figure 13).

FIGURE 13

Cupertino Union School District — Technology Scope and Sequence: Research

LEVEL	TECHNOLOGY SKILLS	POSSIBLE APPLICATIONS	EXAMPLES
one: exploring • Students assisted by teacher • Students investigate electronic media sources to find information for task • Students read/retrieve data from databases & spreadsheets • Students create simple bibliography and citations • Students use simulation software to broaden learning experiences	• Search/navigate CD ROM resources • Use WWW Search engines • Perform single topic searches • Open and read online databases • Read & interpret graphs & tables & databases • Use software templates for bibliographies/citations • Run Simulations	• CD Encyclopedias, Atlases • Instructional TV • Laserdiscs • Simulations: BodyWorks, Great Ocean Rescue, Oregon Trail	• Outlining • Note taking • Mind mapping • Information compilation in organized manner • Bibliography
two: composing • Students assisted by peers/teachers • Students use electronic media features to efficiently select pertinent information • Students download files from the Web which make information locally accessible • Students cite information in appropriate manner • Students narrow search parameters by using more than one word • Students communicate with experts via online discussion groups	• Use notepad or note-taking features of CD • Edit/save skills cut, copy, paste skills • Download text, graphics, video, sound... • Save/Organize data in folders on hard drive • Create formats for bibliographies/citations • Perform Boolean searches (and/or/not...) • Use e-mail & online chat rooms/forums/ bulletin boards	• Netscape: Yahoo, Web Crawler, Excite... • Word processor • Databases/ Spreadsheets • TOM or TOM Jr. • Online card catalogs, periodicals, indexes	• Footnotes and other citations • Initiate and participate in on-line chats
three: refining • Students independently select and use software and devices • Students compile information for complex research project/problem • Students use multiple sources including CD ROMS, ITV, Internet & WWW • Students compare, analyze, synthesize information from dowloaded files	• Use technology/software to organize and interpret collected information • Create Mind Maps, Outlines, Databases, Graphs/Charts/Tables...	• What on Earth, X-Press • Inspiration • MS/Claris Works • MS Word	• Compare and contrast collected information

Cupertino Union School District — Technology Scope and Sequence: Data Organizing and Analyzing

LEVEL	TECHNOLOGY SKILLS	POSSIBLE APPLICATIONS	EXAMPLES
one: exploring **Database** • Students investigate existing database in whole group setting • Students create whole group database and input data • Students learn database terminology **Spreadsheet** • Students create whole group spreadsheet and inputs information • Students produce whole group graph/chart • Students learn spreadsheet terminology	• Sort (filter), find, match to meet one condition • Create fields, format fields, enter data • Know terms - field, records, views (data, list, design, report) • Enter label and value • Use "make chart" feature • Know terms - columns, rows, cells	• The Graph Club • Cruncher • Microsoft/Claris Works	• Student information • Favorites • Animals • Reading log • Class surveys
two: composing **Database** • Students assisted by peers/teachers to created database • Students manipulate, present, and analyze data to convey information **Spreadsheet** • Students assisted by peers/teachers to create spreadsheet • creates graph/chart • Students use simple formulas • Students use editing features	• Create fields, format field, enter data • Sort (filter) to meet more than one condition • Print using report feature • Enter label and value • Use make and define chart feature • Know that formulas begin with "=" (multiply, subtract...) • Use paste function (sum, average...) • Edit - fill right & down	• FileMaker Pro	• Presidents • States • Explorers • Missions • Literature • Budget
three: refining **Database** • Students independently create effective databases • Students use more sophisticated filters and formatting **Spreadsheet** • Students independently create effective spreadsheets & graphs/charts • Students manipulate values to explore cause and effect relationships • Students use more sophisticated formulas and formatting • Students use more sophisticated chart features	• Creates appropriate fields and design layout • Creates filters using multiple operators (equals, contains, less than...) • Format fields (text, number, date, time) • Design appropriate labels and values • Input different values • Use paste function (percent, square root, absolute value...) • Format cells (test, number, date, time) • Use draw features to enhance graph/chart	• Excel	• Use database information for reports and projects • Polyhedraville • Recipes

Cupertino Union School District

Technology Scope and Sequence
Desktop Publishing

LEVEL	TECHNOLOGY SKILLS	POSSIBLE APPLICATIONS/DEVICES	EXAMPLES
one: exploring • Students assisted by teacher • Students explore basic word processing functions to produce sentences • Students investigate basic drawing tools • Students investigate basic paint tools	• Basic word processing functions – insert, delete, highlight... • Basic drawing tools – line, shapes, eraser... • Basic paint tools – brush, spray can, patterns...	• Easybook • Storybook Weaver • KidPix • KidWorks 2 • Microsoft/Claris Works	• Letters • Story/Narrative • Picture and/or text • Picture with label
two: composing • Students assisted by peers/teacher formats and edits text • Students import, alter, and customize basic graphics/clip art • Students use two programs to produce a final product	• Formatting skills – font, style, justify, tabs, page breaks, margins, page setup • Editing skills – cut, copy, paste, spell check • Graphic skills – importing, sizing... • Uses scrapbook	• Writing Center • Student Writing Center • Works • CD-ROM resources • Use clip art programs • Printshop, Bannermania	• Newsletter • Report • Letters • Posters, signs, cards, banners • Books • Brochures
three: refining • Students independently select and use software and devices • Students import graphics using peripherals • Students add visual elements to the text • Students use sophisticated word-processing features • Students use three or more programs to produce a final product	• Import graphic skills – digitized images, scanning, quicktake/cam... • Visual elements – columns, graphs, tables, borders, shading... • Word-processing features – header/footer, footnote, Thesaurus	• Works • Pagemaker • Student Writing Center • Word • Electronic Resources – CDs, encyclopedia, online • Digitized images • Scanner • Quicktake/cam	• Newspaper • Yearbook • Complex Report • Advertisements • Magazines

Cupertino Union School District

Technology Scope and Sequence
Multi/Hypermedia

LEVEL	TECHNOLOGY SKILLS	POSSIBLE APPLICATIONS/DEVICES	EXAMPLES
one: exploring • Students assisted by teacher • Students use tools to create buttons, text, draw pictures, & import clip art • Students use stand-alone devices to support presentation • Students create a simple presentation including text and pictures	• Use text, buttons, & painting tools • Imports/paste clip art • Use video, laserdiscs, CD-ROM	• Hyperstudio • Hypercard • Mediatext • Digital Chisel • KidPix/Slideshow • Word processing • VCR • CD-ROM • Laserdiscs	• Slideshow • Short stack • Using remote control to access a visual aid • Biography • Creative stories
two: composing • Students assisted by peers/teacher • Students use tools to import graphics from devices • Students create presentations which include attractive layout, easy navigation and meaningful content	• Use scanner, CD-ROMs, internet, digital cameras, videocameras as a graphic source • Create animation • Convert video to quicktime	• Scanner • Quicktake/cam • Laserdisc • CD-ROMs, audio & photo • Netscape/AOL • Videocamera • Apple Video Player	• Reports • Electronic newspaper • Tutorial • Video book report
three: refining • Students independently select and use software and devices • Students use tools to integrate sound, video, CDs and access the Internet... • Student create clear presentation which require research, formatting, & skillful delivery	• Create Internet links • Import sound files • Edit video and sound • Work in a scripting language	• Simpletext • Avid VideoShop • HTML, PageMill • HyperLogo, HyperTalk	• Commercial • Web page

Source: Cupertino Union School District. Draft April 29, 1997.

Technology Proficiencies in Promising Projects

"Technology skills are a lot like cooking. While it is important to know how to crack an egg, measure out ingredients, or grate cheese, it's just not a soufflé if you can't put it all together."[39] Increasingly, schools are finding that the best way to teach students the technology skills they need to be productive and facile with technology is not by teaching egg-cracking or cheese-grating but by giving students projects in which technology is one of the many necessary tools for creating an authentic production or solution to a problem.

What does it look like when students use technology in real contexts? In collaborative telecommunications-based science projects such as GLOBE (http://www.globe.gov/), Kids as Global Scientists (www.kgs.colorado.edu), or Global Lab (http://globallab.terc.edu), students conduct research in their home community and share the data with colleagues around the world. Thus, they develop competence with technological tools at the same time they are developing research skills, content knowledge, and the ability to collaborate with peers and adults, both in the classroom and at a distance.

FIGURE 14

The Primavera was painted by Botticelli in 1482, during the Italian Renaissance. The word primavera translates as "spring," deriving from the roots "first-green." The mood of the painting is joyful and celebratory. This narrative piece captures the characters in mid-motion. Botticelli's idealism is reflected in the perfection of bodies and scenery. Their diaphanous garments and graceful poses contribute to the ethereal atmosphere throughout the painting. Preserved in eternal drama, they appear vulnerable to change.

The story of this painting begins on the right, with Zephyr's (wind god) pursuit of the nymph Chloris, who clings to Flora, the goddess of flowers. In the center, yet furthest from the viewer, Venus, the goddess of love and beauty, is the most important representative of springtime. Above her, flies chubby, little Cupid. On the left, the three graces are forever dancing. While, on the far left, Mercury stands mysteriously, with his back to the scene.

The motion, or changes, occuring physically within the painting connect to the historical movements of Botticelli's era. During this time, new philosophies were being incorporated into the arts. Primavera is an example of Botticelli's use of Neo-Platonism, which involves a blending of religious connotations with classical mythology. (To learn more about his specific use of Neo-Platonism see the pages on Venus.)

Photo reproduced by permission, Erich Lessing/Art Resource, NY.
Source: New Jersey Princeton High School Web site.

In New Jersey's Princeton High School, world history students created a virtual museum (http://www.prs.k12.nj.us/Schools/PHS/History/World_History/) in which they selected, studied, and built Web pages for "clickable masterpieces" that support their studies (see figure 14). Their analyses integrate various topics (e.g., history, mythology, geography, religion, and cultural information) in the context of artistic approaches taken by the artists and the messages found in their works. As they isolate small portions of the paintings for further discussion, the students research deeper into the various layers of meaning they find in the artworks. When asked the value of supplementing their world history studies with this time-consuming technology activity, students report that, because they are presenting their work on the Internet, where it can be viewed by anyone around the world, they have to be clear, accurate, and thoughtful in their analyses and presentations. As one student put it, "Because I'm teaching it to someone else, I really have to understand it myself."[40]

Few large-scale studies have documented this form of learning. In a recently released study conducted by the Center for Applied Special Technology (CAST) and sponsored by the Council of Great City Schools and the Scholastic Network, students who developed projects using the Internet were matched against a similar class doing traditional projects. More than 500 fourth- and sixth-grade students in 28 elementary and middle school classes from seven large urban districts across the United States were divided into two groups, an experimental group and a control group. The classes in the experimental group had on-line access to the Scholastic Network and the Internet; the control classes did not. Each group completed projects on civil rights—a topic common to the curriculum of both grades. Independent evaluators were asked to rate the projects, not knowing which group had submitted which project. The students with on-line access received higher scores in all nine learning measures, and their scores were statistically significant for five of the nine measures, including the ability to

- Present their work effectively
- State a civil rights issue
- Present a full picture
- Bring together different points of view
- Produce a complete project

The students who used the network became confident, over the course of the study, of their ability to carry out and present a research project; students without on-line access lacked confidence in their research skills.

Teachers working with the experimental group reported that their students

- Learned to find information quickly
- Draw resources from a large number of sources in a wide variety of formats
- Deal with information in ways that made the material relevant to their lives
- Learned from other students, the teacher, and the community at large using e-mail and message boards

Cutting-edge applications of technology, many funded by the federal government, suggest areas where technology may become embedded in the content and process of learning. For example, in the Virtual Canyon project—supported by a two-year National Science Foundation Networking in Education grant—students in elementary, middle, and high schools in the Monterey Peninsula Unified School District are collaborating with scientists from local universities and the Monterey Bay Aquarium and Research Institute (MBARI) to design and create field guides on the World Wide Web, based on undersea explorations of the huge canyon beneath the Monterey Bay. Using dynamic video collected by MBARI's remotely controlled vehicle from the research ship *The Point Lobos*, the teams of students, teachers, and scientists are developing a learning system wherein content, technology, expertise, and knowledge meet in a user-oriented on-line environment. The Virtual Canyon prototype is a living research lab, built around a model in which students engage in exploration, research, and publication. As they conduct their research and publish reports on the Web, they develop expertise about the creatures and conditions they are studying, the scientific process itself, and how to use technology for communication and research. Some of the criteria project leaders are considering using to evaluate it include skills acquisition (in technology and science), facts acquisition, the ability to generalize and synthesize from inquiries, critical thinking and evaluation of information, context transfer, and communications and collaboration skills. Evaluators are also hoping that users can learn to follow a self-directed path to answer their own questions and do their own problem solving. Finally, they will evaluate the prototype project to see if it can enable broad participation by scientists in the research and education of students.[41]

The curriculum goals and projects described on pages 27–44 are aimed at helping students develop effective technology skills that will assure they use technology to support learning throughout the curriculum. To bring these goals to fruition and to move beyond isolated promising projects, however, several key policy issues need to be addressed, including teacher competence, equity, testing issues, and resource allocations decisions at the state, district, and school levels.

TEACHER ISSUES

Teachers come to their jobs knowing the content and the pedagogy, but when it comes to technology, the teachers are learning along with, and often after, the students. If students are expected to develop technological fluency, their teachers must also possess it. Although most teachers are eager to use the new technologies, few were taught to teach with computers or other technological tools.[42]

States are addressing this issue by developing standards for teachers' technological competency at the same time they are developing them for students. In an informal survey conducted by the U.S. Department of Education, 20 states reported having in place, or under development, technology standards for teachers, and three more said they are under consideration (19 states had not responded at the time of writing). Thirty-five states require courses or proficiencies in educational technology for those seeking a teaching license; four states require the courses or proficiencies for recertification.

Technology may be the only area in which the skills of teachers in the classroom are being tested along with, or even instead of, student skills. This is a significant change for the educational paradigm, for it is easier to evaluate the technological skills of entry-level teachers than those of teachers already in the classroom. Although a delicate issue, school systems may be putting the cart before the horse by testing students without finding out how much their teachers know. Thus, before conducting student technology skills testing, the Department of Defense Education Authority (DoDEA) plans to assess the technology skills of their teachers.

Although the teacher assessment will be used to develop plans for teacher training, it is looked on with concern by the union, especially if the results affect promotion, placement, or merit pay. Similar concerns have been registered when anything more than a survey of teacher skills is being considered. But others believe that standards are necessary to assure that teachers get the training and support they need.

Personal Proficiency

Instructional Proficiency

In North Carolina and California, technology competency standards for educators are being developed along with student technology skills measures. California educators, including administrators as well as teachers, are measured on four levels: personal proficiency, instructional proficiency, mentoring proficiency, and leadership proficiency. Objectives and performance standards for each level are specified, just as in the student component. Additionally, the educator standards suggest how educators can demonstrate their mastery of each skill level, and what part ongoing assessment plays in periodic performance assessments. To demonstrate mastery at the personal proficiency level, educators can pass a skills test approved by the appropriate credentialing commission or get a degree from a college or university that the Commission on Teacher Credentialing has certified as having graduation requirements that equal or exceed the required skills. For meeting the standards above level one (personal proficiency), portfolios, observations, and commendations of fellow educators are taken as measures.

Mentoring Proficiency

Leadership Proficiency

Some places have taken a hard line, issuing a wake-up call for those in leadership positions. Jefferson County, signaling its view that facility with technology is a necessary skill for those seeking administrative positions, requires all those seeking to enter positions at the principal, assistant principal, or other administrative level, to take a technology test, which is administered electronically. Those uncomfortable with this requirement have two options—to (1) take the free training offered by the district that will give them the necessary skills to pass the test or (2) forgo the opportunity to move into a leadership position with the county schools.

TESTING ISSUES

How much testing is necessary to ascertain student (or teacher) technological fluency? As Texas discovered after developing its computer-based technology skills assessment, creating separate tests for students and teachers may become politically unpopular if parents, school boards, and legislatures cannot afford the time or expense of mandated testing programs. The costs of developing, administering, and reporting test results are considerable.

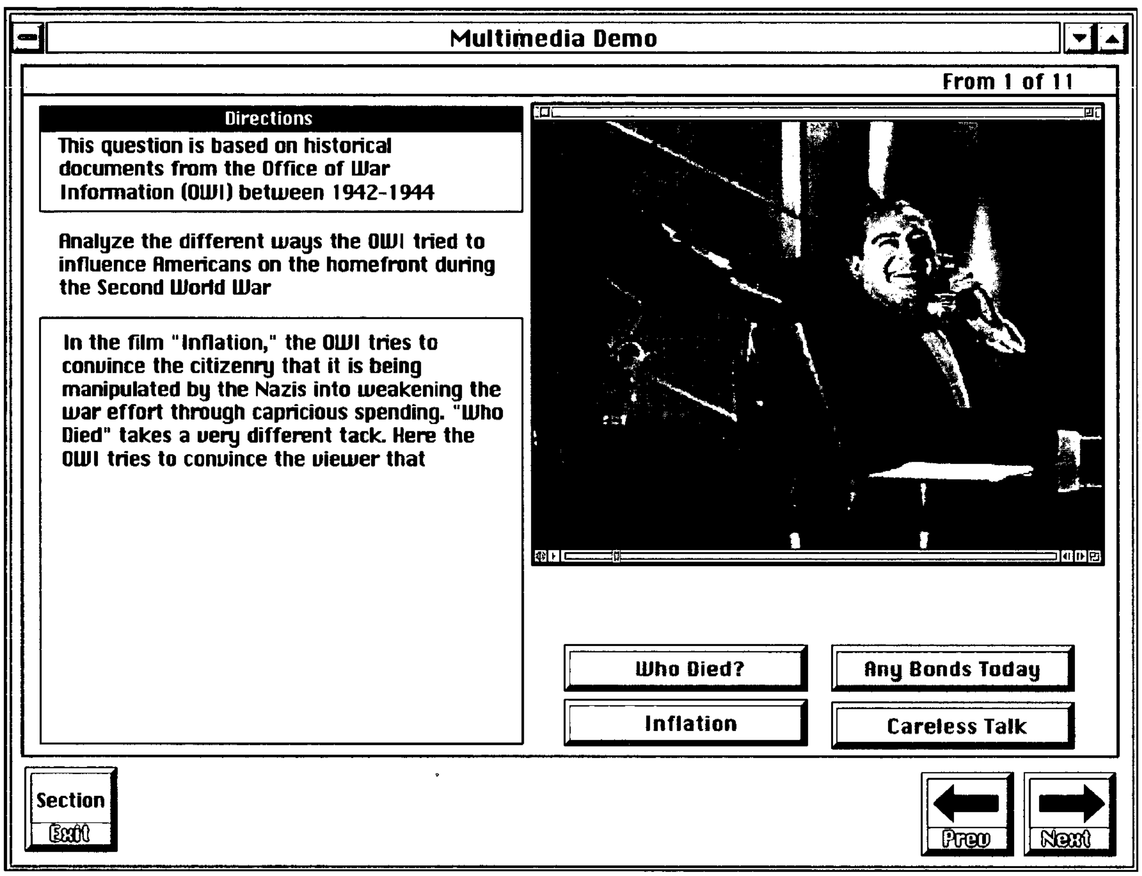
Furthermore, once the commitment has been made to test students, educators must agree on how this testing should be conducted. The debates raging around the issue of performance assessment confirm that there are no simple solutions. If schools are seeking to use a constructivist approach, with students creating products that call for them to apply existing skills to solve what one educator called "fat problems"—those rich in creative and analytical possibilities—can we continue to build assessments around limited multiple-choice tests of factual recall? Despite the growing interest in performance-based assessment measures, these tests are expensive to develop, administer, and score. Furthermore, the interpretation of results can be problematic, especially if students are tested in groups as well as individually.

These concerns also plague the question of testing technology skills. As the Jefferson County schools found, even the most traditional testing of computer skills is complicated by needing a working computer to authentically measure that learning. When that testing becomes more problem-based or "authentic," as in the Demonstrations of Quality Work items being tested this year, far greater expense is involved.

Despite such barriers, those involved in large-scale assessment have noted the growth in computer-based tests. Most (e.g., the Graduate Record Examinations General Test, Praxis I, the SAT I: Reasoning, ACT's COMPASS, and the College Board's computerized placement tests) use traditional constructs with behavioral test designs and many of the same test items and graphics found on pencil and paper tests.[43] Nonetheless, there are signs of change. Multimedia (video, audio, and animation) provide the opportunity to make the presentation, the content, and the intellectual constructs they assess more dynamic.[44]

The advent of large testing centers with technological capabilities, combined with advances in technology, psychometrics, and understandings in cognitive science, suggests a next generation of electronic tests. More than automated pencil and paper tests, their qualitative difference will lie in the kinds of items that, for the first time, can deliver large-scale assessments in a cost-effective method. The problem is not so much a shift in design as a shift in our expectations for testing. For example, to analyze the impact of historical artifacts, a student is presented with materials from a variety of sources—including texts, speeches, news

FIGURE 15



Note: Copyright (c) Educational Testing Service, 1996. The scene depicted in this item comes from the CD-ROM, "Powers of Persuasion: The Art of Propaganda in World War II," produced by Fife and Drum Software, Silver Spring, MD, from records of the National Archives in Washington, D.C. A partially complete student response is shown in the answer box on the lower left.

Source: R.E. Bennett, et al, "Using Multimedia in Large-Scale Computer-Based Testing Programs," Princeton, NJ: ETS, March, 1997. Reprinted by permission of Educational Testing Service, the copyright owner.

articles, political cartoons, and maps, video and radio reports, animation representing troop movements, populations trends, and so on. A student selects a document to view or listen to and then writes an essay analyzing, for example, the way the Office of War Information tried to influence Americans at home during the war (see figure 15). In considering how the form and function of the test come together, the Educational Testing Services researcher noted that

> The self-reflexive nature of this example (i.e., employing multimedia to ask students to analyze the use of multimedia) makes it ideal as a medium for assessing the ability to interpret different kinds of twentieth-century documents. Promoting the role of government propaganda during this period, and the impact of the Second World War on the homefront, necessitated, in fact, that we have students examine and analyze nonprint sources. Historiographically, therefore, both the materials and the questions were appropriate to the domain of knowledge being assessed.

Do assessments like this also measure second-level skills of technological fluency—facility using technology as well as understanding its specialized rules and metaphors? Until we create those kinds of assessments, we will not be able to answer the question, but the financial risks are considerable, especially for large-scale, high-stakes tests.

ISSUES OF EQUITY

We have stressed the importance of assuring equal access to technology for all students, but there has been less discussion around the issue of equity in technology assessment.

If next-generation technology-based testing becomes the norm, will students be at a disadvantage if they come from schools where technology is not widely used? If some teachers choose not to use technology, will they be placing their students at risk? These questions suggest that all educators must agree on the most appropriate ways to assess both students' knowledge and information-age skills and on policies to assure students are equally prepared to meet those assessments. For high-stakes testing—with the results having the same kind of impact on students as do the SAT and the GRE, or on schools and their staff, as do some state testing programs like Maryland's MSPAP—then the tests must be fair and appropriate measures of necessary skills.

What happens when educators focus their resources on teaching students first-level technology skills (that is, how to work the technology) but ignore the second-level skills of symbolic representation and knowledge integration, leading to deeper understandings and alternative ways of representing information? Will some students, then, graduate with technical skills only, while others will become symbolic analysts and knowledge workers?

SURVEYS, TESTS, AND RESOURCE ALLOCATIONS

What gives districts and states the information they need to make decisions on which to frame policy? Tests can confirm what may be anecdotally observed—as when the Jefferson County testing showed greater variation in high school students' skills than among elementary school students, confirming the higher computer-to-student ratio at the high school level. This kind of data can determine resource allocations (e.g., placing more computers in high schools in Jefferson County) as well as curriculum measures (making computer courses required, rather than elective, so that all students will have equal baseline skills).

Can surveys about technology use give us equally valuable information at less cost and burden to students and teachers (e.g., the data collected from SAT-takers on their access to technology at school and at home)? An interesting variation on surveys as technology skills outcome measures is the scale reporting elementary, middle, and high school technology outcomes in the Bellingham Public Schools (see http://www.bham.wednet.edu/elmankat.htm). Called a "Mankato scale," after the scale developed by the Mankato (Minnesota) Public Schools to measure the growth of staff technology skills, students use it to self-report what they can do with computers and multimedia, file management, presentation resources, information searching, and other technology-supported activities.

To better understand how technology skills are best developed, assessed, and supported, much needs to be done. There is little agreement on common data elements that could be collected across projects to give a clearer picture of outcomes. Schools and school systems are hungry for assistance in this area—data they should collect, activities they should observe and record, indices that go beyond test scores, criteria that suggest when to make midcourse adjustments, best practices they can adopt, and models they can emulate. Can it be shown that the development of technology skills, that is, those "first-level" skills with and knowledge of technology, make students more successful in their continuing educational studies or in the workplace? Even more importantly, can it be shown that second-level skills—facility in solving complex questions with the assistance of technological resources, or the ability to understand and communicate with multiple forms of information—make students more successful learners in all areas?

A number of vehicles exist for expanded research in this area, if research is given priority attention. For example, the Technology Challenge Grants, with their cutting-edge applications of technologies in the classroom, should be mined as a rich evaluative data source on the links between technology implementation and measures of learning and educational enhancement. What does the introduction of advanced technologies do for traditional content, pedagogy, and assessment? Does it force the issue of curricular reform? What are the conditions that make this occur? How can policymakers evaluate the impact of these changes? Similarly, the Federal Technology Literacy Challenge Funds distributed among the states, with their focus on technology planning, can provide important data on technology's impact on many areas related to school structure and organization, but especially as related to meeting content, standards, and assessment goals. However, unless states are encouraged to ask the right questions of schools and projects, and unless they are supported in the task of collecting comparable data and sharing their research, the answers may not be forthcoming. With the substantial investments in technology at all levels, greater funding and dissemination of research will assist educators and policymakers at all levels in implementing technology goals and applications.

Concluding Comments

Developing standards in a changing environment is not an easy task. If teaching with ever-changing technologies is like building an airplane while it is in flight, then defining and assessing what skills are needed to work and learn with technology is like developing a flight plan en route. Chris Dede, one of education's most articulate futurists, suggests, "I don't think anybody really knows what this next generation of students is going to need in the way of knowledge and skills. We're hard-put to guess what workers are going to need five years from now, let alone a generation from now. Maybe the most important thing about next-generation standards is that they are going to have to be flexible and evolving, rather than fixed and inflexible. This creates some 'wiggle room' in a way that fixed standards don't."[45]

Nonetheless, the reality of today's technological environment means that educators must address the issue of technological fluency for all students, and not expect that it will automatically occur through the magic of just having technology on hand. Furthermore, the growing trend to consider technology skills in the context of broader learning goals can assist in ensuring that technology is utilized in the most productive manner. Can these learning standards, and the assessments that measure success in reaching them, be shaped in a flexible enough fashion that a vision for the future still allows for important "wiggle room" in a changing environment? It is a great challenge, but perhaps what is most exciting and promising is that the demands of technology are forcing educators to have conversations about broad goals for teaching and learning in the twenty-first century. Through these conversations and the policies that evolve from them, America's children may indeed develop the skills and wisdom they will need to meet their dreams.

About the Author

Kathleen Fulton is associate director of the Center for Learning and Educational Technology at the University of Maryland, College Park. Prior to this position, Dr. Fulton was a senior consultant for Issue Dynamics, Inc., a Washington, D.C. public affairs consulting firm, where she assisted the Illinois State Board of Education in writing their State Technology Plan and helped the Public Broadcasting Service develop a proposal for an on-line resource center for teachers. Dr. Fulton has also served as senior analyst and project director for the U.S. Congress's Office of Technology Assessment.

Endnotes

1 An excellent summary of this research can be found in "The Effectiveness of Using Technology in K-12 Education: A Preliminary Framework and Review," a report prepared for the U.S. Department of Education by Beatrice F. Birman, Rita J. Kirshstein, Douglas A. Levin, Nancy Matheson, and Maria Stephens (Washington, D.C.: American Instates for Research, January 1997).

2 Reginald Gregoier, R. Bracewell, and T. Laferriere "The Contribution of New Technologies to Learning and Teaching in Elementary and Secondary Schools," a collaboration of Laval University and McGill University, August 1, 1996. (http://www.fse.ulaval.ca/fact/tact/fr/html/impactnt.html)

3 U.S. Congress, Office of Technology Assessment, *Teachers and Technology: Making the Connection*. OTA-EHR-616 (Washington, D.C.: U.S. Government Printing Office, April 1995). (http://www.wws.princeton.edu/~ota/index.html)

4 National Commission on Excellence in Education, U.S. Department of Education, *A Nation at Risk*. (Washington, D.C.: U.S. Government Printing Office, April 1983.)

5 Although titled the "First National Assessment of Computer Competence," there has been none since. Michael E. Martinez and Nancy A. Mead *Computer Competence: The First National Assessment*. (Princeton, N.J.: Educational Testing Service, April 1988.)

6 The College Board, *1996 College-Bound Seniors: A Profile of SAT Program Test Takers*.

7 "Synopsis, Computers in American Schools, 1992: An Overview." Report of the IEA Computers in Education Study. University of Minnesota, February 1, 1994.

8 Willem J. Pelgrum and Tjeerd Plomp, "What Do Students Know, Learn and Think about Computers?" chapter 4 in *Schools, Teachers, Students and Computers: A Cross-National Perspective*, eds. W.J. Pelgrum, Reinen Janssen, I.A.M., and T.J. Plomp (IEA, December 1993). See http://uttou2.to.utwente.nl/comped/fr2/.

9 Ronald Anderson, University of Minnesota, personal communication, June, 1997. Anderson and Henry Becker, University of California at Irvine, will be the principal investigators of the study.

10 B. Berenfeld "Linking Students to the Infosphere," *T.H.E. Journal*, April 1996, pp. 76-82.

11 Illinois State Board of Education, *K-12 Information Technology Plan*, (Springfield, Ill.: 1996), p. 27. See also http://www.isbe.state.il.us/

12 This section draws heavily on conversations with Henry Becker, University of California at Irvine, and his paper "Business Support for American Education: What National Interest Demands, Telecommunications Makes Possible." http://www.gse.uci.edu/VKiosk/Faculty/hank/Reich/SCANSColeman.html

13 Secretary's Commission on Achieving Necessary Skills, *What Work Requires of Schools* (Washington, D.C.: U.S. Department of Labor, 1991).

14 Reich, Robert B. *The Work of Nations*. (New York: Random House, 1991.) See also U.S. Congress, Office of Technology Assessment, *Worker Training: Competing in the New International Economy* OTA-ITE-457. (Washington, D.C.: U.S. Government Printing Office, 1990) or http://www.wws.princeton.edu/~ota/ns20/year_f.html

15 Ibid., pp. 229-230.

16 Cognition and Technology Group at Vanderbilt, Learning Technology Center, Peabody College "Looking at Technology in Context: A Framework for Understanding Technology and Education Research," in D.C. Beringer and K.C. Calfee, eds. *Handbook of Educational Psychology* (New York: Simon and Schuster-Macmillan, 1996).

17 U.S. Congress, Office of Technology Assessment, *Education and Technology: Future Visions* (Washington, D.C.: U.S. Government Printing Office, September 1995).

18 Barbara Means et al., *Using Technology to Support Education Reform*. SRI International for U.S. Department of Education (Washington, D.C.: U.S. Government Printing Office, 1993), p. 2.

19 James Bosco, "Schooling and Learning in a Information Society." OTA contractor report, November, 1994, NTIS No. 95-172227.

20 National Commission on Excellence in Education, "Nation at Risk."

21 http://www.ed.gov/Technology/Plan/

22 MCREL, the Midcontinent Regional Education Laboratory, has assembled these content standards and produced a number of documents useful to educators. See http://ww.mcrel.org/standards-benchmarks/docs/chap195.html

23 David Mintz, National Center for Education and the Economy, personal communication, August, 1997. See also Marc Tucker, "National Education Standards: Ready Now!" New York Times, December 5, 1996.

24 "Technology for All Americans: A Rationale and Structure for the Study of Technology." (Reston, VA: International Technology Education Association, 1996.)

25 AASL/AECT Vision Committee, "Information Literacy Standards for Student Learning," working draft, summer, 1997.

26 Thomas Mendenhall, president, Smith College, at a student convocation, 1963.

27 U.S. Department of Education. "State Technology Trends," working draft, 8/25/97.

28 http://www.dpi.state.nc.us/Curriculum/Computer.skills/compcurr.html#intro

29 Materials provided by Barbara Shriver, director of educational technology, Department of Defense Education Authority, June, 1997.

30 Information based on personal communication, Barbara Schriver, director of educational technology, Department of Defense Education Authority, June 4, 1997.

31 Materials provided by Anita Givens, senior director, and Karen Kahan, educational technology specialist, Texas Education Agency, June, 1997.

32 "Connect, Compute, and Compete," report of the California Education Technology Task Force, July 8, 1996.

33 Education Council for Technology in Learning, *Education Council for Technology in Learning Recommendations Regarding Technology-Based Content and Performance Standards*, draft, California Department of Education.

34 Oregon Education Media Association, Oregon Information Literacy Guidelines, 1997 (draft 2/97).

35 Illinois State Board of Education, p. 26.

36 Ibid.

37 Mary Jo Milburn, instructional computer specialist, Computer Education Support Unit, Jefferson County Public Schools, personal communications, June, 1997.

38 Cupertino Union School District, "Technology Scope and Sequence," work in progress, Cupertino, California, April 29, 1997.

39 Chris Dede, National Science Foundation, personal communication, June 1997.

40 Discovery Communications, "Computers: Hype or Hope?" part of the *School Stories Series* (to air October, 12, and December 28, 1997) Discovery Channel (http://school.discovery.com).

41 For more information, see www.virtual-canyon.org

42 U.S. Congress, Office of Technology Assessment, *Teachers and Technology: Making the Connection*.

43 R.E. Bennett, "Speculations on the Future of Large-Scale Educational Assessment," paper presented at the National Research Council's Board on Testing and Assessment, Orlando, February, 1997.

44 R.E. Bennett et al., *Using Multimedia in Large-scale Computer-based Testing Programs* (Princeton, N.J.: Educational Testing Service, March, 1997).

45 NEA Center for Educational Technology, *Conversations on Technology with Chris Dede and Kathleen Fulton*, working draft, 1997.

THE MILKEN EXCHANGE ON EDUCATION TECHNOLOGY NATIONAL ADVISORY BOARD

Cheryl Lemke, DIRECTOR
Vice President, Education Technology

Gaston Caperton, CHAIR
West Virginia Governor, 1988–1996

Richard Benz
Milken Educator, Ohio

David Brittain
President, International Society for Technology in Education (ISTE), and former Florida Technology Director

Michael A. Fox
Chair, House Education Committee, Ohio

Elaine Griffin
Milken Educator, Alaska

Cyndi Harrison
Milken Educator, Kansas

Christopher Held
Milken Educator, Washington State

Patrick Kiely
President, Indiana Manufacturers Association, and former state legislator

Barbara Nielsen
South Carolina Superintendent of Schools

Michael Roos
President, LEARN school reform initiative, and former California State Assembly Speaker Pro Tem

Brenda Williams
Technology Director, West Virginia Department of Education

Milken Family Foundation

PROFESSIONAL STAFF

Lowell Milken
President

Dr. Julius Lesner
Executive Vice President

Dr. Thomas C. Boysen
Senior Vice President, Education

Dr. Lewis C. Solmon
Senior Vice President, Senior Scholar

Lawrence Lesser
Senior Vice President, Production

Ralph Finerman
Senior Vice President and Treasurer

Joan Brooks
Vice President, Milken Family Foundation National Educator Awards

Dr. Cheryl Fagnano
Vice President, Education Research and Programs

Cheryl Lemke
Vice President, Education Technology

Christopher M. Crain
Vice President and General Counsel

Katherine Nouri Hughes
Vice President, Communications

Michael Reese
Vice President, Government and Public Affairs

Ian Noah
Vice President, Mike's Math Club

Joni Milken-Noah
Vice President, Mike's Math Club

Steven J. Cobb
Chief Financial Officer

Barbara Klein
Program Director, Festival for Youth

Dahlia Geilman
Program Administrator, Grants

Rosey Grier
Program Administrator, Community Affairs

Rebecca Rona
Program Administrator, Music Archive

Tamara Schiff
Education Research Associate

MILKEN
FAMILY
FOUNDATION

Milken Exchange on Education Technology
1250 Fourth Street
Santa Monica, California 90401-1353
(310) 998-2825 telephone
(310) 998-2899 facsimile
e-mail: clemke@mff.org
Web site: www.mff.org

IR

EXECUTIVE SUMMARY

Learning in a Digital Age: Insights into the Issues

The Skills Students Need for Technological Fluency

Milken
CHANGE
on education technology

Learning in a Digital Age: Insights into the Issues

The Skills Students Need for Technological Fluency

Kathleen Fulton

Center for Learning and Educational Technology
University of Maryland

A Publication of the Milken Exchange on Education Technology

The computer is no longer "the new kid in school." Since the early 1980s, when computers were first used in schools, more than $3 billion has been spent on hardware, software, teacher training, and connections. But are our students technologically literate or, as many have begun to demand, technologically fluent? These are important questions for America's success—and that of its children—in the information age, but we need a consensus on what it means for students to be facile with technology. Is there a set of "necessary skills" that define technological fluency? Can this set be expanded to include the broader communication and information skills students will need in the global economy of the twenty-first century?

In considering this issue, we must recognize that the effective use of technology to develop learning, communication, and information skills is the result of many factors, chief of which are the teacher, her competence and ability to shape technology-based learning activities to meet students' learning needs. Other factors—software, access, school support in allowing time and experimentation to try new things—all have a place in the impact technology can have on students and their achievement, as has been noted in many past analyses.[i] But there is another key element, one that may seem obvious, but which in fact has been overlooked in many past studies of computer-based learning in the classroom. One recent study put it succinctly: "The effect of computer-based learning technologies in facilitating student learning and performance is seen only when participants have the knowledge and skill to use the technology."[ii] While this may seem self-evident, the authors report that it was perhaps because of the "assumed power of the technology" that past researchers have not evaluated the knowledge and skill base necessary for students to use technology most effectively.

CHANGING DEFINITIONS

What do students need to know and do with technology? Unlike the more stable content and goals we have for other areas of school study, technology continues to change and evolve; with these changes come ever-new goals for how technology should serve learning, and what students should know about technology. A review of the "prevailing wisdom" about appropriate technology use since the early 1980s takes one down an ever-turning road that includes programming in BASIC, then with LOGO; and on to drill and practice applications on integrated systems; word-processing and curriculum-specific tools like history databases, simulations, and microcomputer-based labs; then multimedia; the Internet; and now Web page design. While there may be some logic to this progression, the reality is that, just as educators get their arms around one approach, with the attendant investments in software, training and possible curricular readjustments, the messages about appropriate technology use change.

PAST NATIONAL AND INTERNATIONAL ASSESSMENTS OF COMPUTER COMPETENCE

These changing expectations have been reflected in past large-scale assessments of "computer competence," such as the 1985-86 National Assessment of Educational Progress (NAEP) national assessment of computer competence. This national sampling of third-, seventh- and eleventh-grade students assessed their knowledge and skills in using a computer, using questions dealing with recognition or recall of specific facts, and procedures related to computer use.

Measures of computer literacy, not unlike those in the first NAEP study, were targeted in the Computers in Education Study undertaken by the International Association for the Evaluation of Educational Achievement (IEA).[iii] The 1992 study tested and analyzed basic computer knowledge and skills in 12 countries, with test items developed and reviewed by an international team, and translated into several languages. The curriculum analyses made from a 1989 study revealed little consensus, either within countries or across countries, regarding computer goals, making it a challenge to design an assessment instrument. The instrument that was developed, called the Functional Information Technology Test, tested what students needed to function effectively with information-related tasks, with test items built around concepts, computer handling, and applications.

FACTORS INFLUENCING TODAY'S DEFINITION OF NECESSARY SKILLS

While past national and international assessments are important in helping to understand how far we have come as a nation in student technological understandings and skills, it is useful to bring our focus to the present, and consider the factors that influence today's definitions of necessary skills for technological fluency. These include the demands driven by expanding information and communication resources, business influences, national leadership, and the curriculum standards movement. Taken together, they suggest today's definition of technological literacy as a combination of what separately have been called information skills and literacy, communications skills and literacy, and technology skills necessary to function in a technological environment. Today's definitions of technological fluency evolve from the intersection created by the technology pull—that is, advances in what the technology can do, and how it is used in the world beyond the classroom—as well as the pedagogical push—changing views of learning reflected in the educational standards and assessments that drive instruction.

Information Literacy in the Age of the Internet Concern about information literacy predates the computer age. In language arts, there has long been an emphasis on teaching students to develop skills they need in order to analyze the written word and the messages found therein. With the growing influence of television in our daily lives, many have called for media literacy that gives students tools to interpret, critique, and evaluate what they see on television and in movies and videos. However, today's rapid growth of the Internet and the access it provides to large amounts of information has ignited a firestorm of concern regarding the need for increased attention to information literacy. Unlike the information students receive from earlier forms of media—textbooks, television, documentaries, library materials—all of which have been carefully researched, documented, and selected for publication and presentation, especially when used in educational settings—what comes across on the Internet is "undigested" information, provided by expert and novice alike, scholars and shysters, pedagogues and pedophiles. The days when teachers and parents were able to control and orchestrate all the information presented to students are past. The technology pull of the Internet will force the issue of developing broader information literacy skills for all students if we expect them to sort the wheat from the chaff, the true from the untrue, the rumor from the real. In order to work, learn, and flourish in what has been called the "Infosphere,"[iv] students will need to become skilled in

- Finding information from a variety of sources
- Evaluating information
- Making critical judgments about its value, reliability, and validity
- Creating and distributing information and knowledge via the many communication forms—text, video, graphics, conversation—that come together in today's technology-mediated communications formats

Business Demands[v] The business community has been an important voice calling for students to develop technological literacy. As early as 1991, in the Department of Labor report *What Work Requires of Students,*[vi] the Secretary's Commission on Achieving Necessary Skills (SCANS) identified skills and attributes necessary for employment in the workplace:

- Resource allocation skills—handling time, money, materials, space, and staff
- Interpersonal skills—working on teams, teaching others, serving customers, leading, negotiating, and working well with people from culturally diverse backgrounds
- Information skills—acquiring and evaluating data, organizing and maintaining files, interpreting and communicating, and using computers to process information
- Systems skills—understanding social, organizational, and technological systems, monitoring and correcting performance, and designing or improving systems
- Technology skills—selecting equipment and tools, applying technology to specific tasks, and maintaining and troubleshooting technologies

These skills are required in the expanding global economy in which American business must operate. Success in this global economy requires high performance industries—those that can create new products or services that are of high quality or those that add value to existing goods and services. In turn, these high-performance industries will be built around a workforce composed of individuals who are flexible learners, able to change, adapt, and move with the opportunities technology and innovation offer. Management at all levels will require a cadre of "symbolic analysts," individuals who are competent in working with abstractions, facile with systems thinking, comfortable with experimentation, and can work collaboratively to solve problems.

New Views of Learning The factory-like organization of schools of the industrial age were structured to support a transmission model of education in which teaching was telling, and learning was memorizing. New views of cognition support[vii] a constructivist view that suggests "advanced skills of comprehension, reasoning, composition, and experimentation are acquired not through the transmission of facts but through the learner's interaction with content."[viii] This approach takes advantage of a student's natural ability to learn through experience and to "create mental structures...which organize and synthesize the information and experiences which the individual encounters in the world."[ix] Information and communication technologies like the Internet support this approach to teaching and learning, which encourages learning in authentic contexts, collaboration and external supports, and use of multiple primary source materials and resources, as well as textbooks.

Federal Leadership and National Standards Federal leadership, from the identification of computer literacy as a fourth basic skill in *A Nation at Risk* in 1983, to the current emphasis on educational technology in the Clinton Administration, has brought important attention and resources to the picture.[x] Because the United States, unlike many other countries, does not have a national curriculum, there is an emerging consensus on what students should learn, building on the national curriculum standards developed over the last several years by a range of professional associations. These standards have had a major impact on performance standards developed at the state and district level. Curriculum standards and benchmarks have been developed, or are in the process of being drafted, in the areas of mathematics, science, history, language arts, geography, the arts, civics, economics, foreign languages, health, physical education, and social studies.[xi] They have provided signposts that direct today's state and local standards movement.

STATE AND DISTRICT TECHNOLOGY SKILL STANDARDS AND ASSESSMENTS

Nevertheless, policymakers at the state and district levels continue to struggle with a central dilemma. Should they define and measure learning goals *for* technology, or what can be called first-level technology skills (e.g., learning about technology), or should they instead define and measure the second-level goals for learning *through* technology (e.g., "thinking with computers")? A survey of state technology directors by the Milken Family Foundation in

September, 1997, found that, of the 47 respondents, 13 reported technology skills embedded in curricular standards, three had discrete technology standards, and 17 reported both embedded and discrete standards.

North Carolina provides an interesting example of curriculum standards that separate technology skills as discrete skills to be tested. Illinois provides a contrasting model, where standards for technology are embedded in the benchmarks for the curriculum standards rather than as a separate set of competencies. Neither technology-specific nor grade-level-specific benchmarks, they are built around what is called "six essential learnings in a technological society."[xii] The indicators call for assuring that all students are

- Information seekers, navigators, and evaluators
- Critical thinkers, analyzers, and selectors of information and technologies appropriate to the task
- Creators of knowledge using information resources and technology
- Effective communicators using a variety of appropriate technologies/media
- Technical users
- Responsible citizens in a technological age

School districts, like states, vary in the approaches they take to technology skills standards and assessment. Two contrasting approaches are Jefferson County, Kentucky's delineation of technology-specific skills, and the technology-embedded curriculum adopted by the Cupertino Union School District in California.

EXAMPLES OF TECHNOLOGY PROFICIENCIES DEMONSTRATED IN PROMISING PROJECTS

What does it look like when students use technology in real contexts? In collaborative telecommunications-based science projects such as GLOBE (http://www.globe.gov/), Kids as Global Scientists (www-kgs.colorado.edu), or Global Lab (http://globallab.terc.edu), students conduct research in their home community and share the data with colleagues around the world. Thus, they develop competence with technological tools at the same time they develop research skills, content knowledge, and the ability to collaborate with peers and adults, both in the classroom and at a distance.

In New Jersey's Princeton High School, world history students created a virtual museum in which they selected, studied, and built Web pages for "clickable masterpieces" that support their studies (http://www.prs.k12.nj.us/Schools/PHS/History/World_History/). Their analyses integrate various topics (e.g., history, mythology, geography, religion, and cultural information) in the context of artistic approaches taken by the artists and the messages found in their works. As they isolate small portions of the paintings for further discussion, the students research deeper into the various layers of meaning they find in the art works. When asked the value of supplementing their world history studies with this time-consuming technology activity, students report that, because they are presenting their work on the Internet, where it can be viewed by anyone around the world, they have to be clear, accurate, and thoughtful in their analyses and presentations. As one student put it, "Because I'm teaching it to someone else, I really have to understand it myself."[xiii]

In the Virtual Canyon project—supported by a two-year National Science Foundation Networking in Education grant—students in elementary, middle, and high schools in the Monterey Peninsula Unified School District are collaborating with scientists from local universities and the Monterey Bay Aquarium and Research Institute (MBARI) to design and create field guides on the World Wide Web, based on undersea explorations deep into the wonders of the huge canyon beneath the Monterey Bay. Using dynamic video collected by MBARI's remotely controlled vehicle, the teams of students, teachers, and scientists are developing a learning system wherein content, technology, expertise, and knowledge meet in an ever-growing, user-oriented on-line environment. As the students conduct their research using these resources, and publish reports on the Web, they build expertise about the creatures and conditions they are studying, the scientific process itself, and how to use technology as a tool for communication and research.[xiv]

IMPLICATIONS FOR POLICY

Several key policy issues need to be addressed if we are to move beyond isolated promising projects and into a broader landscape of curriculum and teaching that supports technological fluency for all students.

Teacher Issues If students are expected to develop technological fluency, their teachers must also possess this fluency. While most teachers are eager to use technology, most were not taught to teach with computers and other technological tools.[xv] States are beginning to address this issue by developing standards for teachers' technological competency at the same time they develop them for students. In an informal survey conducted by the U.S. Department of Education, 20 states reported having in place, or under development, technology standards for teachers, and three more said they are under consideration. Thirty-five states require courses or proficiencies in educational technology for those seeking a teaching license, and four states require this for recertification.

Standards and assessments evaluating the technological skills of entry-level teachers are easier to implement than those for teachers already in the classroom. It is a delicate issue, but some school systems realize they may be putting the cart before the horse in testing students without finding out how much their teachers know in the area; and others believe that standards are necessary to assure that teachers get the training and support they need.

Some places have taken the hard line, issuing a wake-up call for those in leadership positions. Jefferson County has used technology testing as a means of signaling the view that facility with technology is a "necessary skill" for those seeking administrative positions. All those seeking to enter positions at the principal, assistant principal, or other administrative levels, must take a technology test, which is administered electronically. Those who are uncomfortable with this requirement have two options—to take the free training offered by the district that will give them the necessary skills to pass the test, or to forgo the opportunity to move into a leadership position with the county schools.

Testing Issues How much testing is necessary to ascertain student (or teacher) technological fluency? The costs of developing, administering, and reporting test results are considerable. Furthermore, once the commitment has been made to test students, educators must agree on how this testing should be conducted. The debates that rage around the issue of performance assessment confirm that there are no simple solutions. If schools seek to develop teaching and learning skills built on a more constructivist approach, with students creating products that call for them to apply existing skills and use these to solve what one educator called "fat problems"—those rich in creative and analytical possibilities—can we continue to build assessments around more limited multiple choice tests of factual recall?

These concerns also plague the question of testing technology skills. As Jefferson County schools found, even the most traditional testing of computer skills is complicated by needing a working computer to authentically measure that learning. Even greater expense is involved when that testing becomes more problem-based or "authentic," as in Jefferson County's Demonstrations of Quality Work items being tested this year. The challenge lies in designing assessments that measure second-level skills of technological fluency—facility in using technology as well as understanding its specialized rules and metaphors. The financial risks involved are considerable, especially for large-scale, high-stakes tests.

Issues of Equity If next-generation technology-based testing becomes the norm, will students be at a disadvantage if they come from schools where technology is not widely used? If some teachers choose not to use technology in their teaching, will they be placing their students at risk? These questions suggest that all educators must agree on the most appropriate ways to assess both students' knowledge and information-age skills, and on policies to assure students are equally prepared to meet those assessments. For high-stakes testing—with results having the same kind of impact on students as do the SAT or GRE, or on schools and their staff as do some state testing programs like Maryland's MSPAP—then the tests must be fair and appropriate measures of necessary skills. This is as true for technology skills as for other academic skills.

Another equity issue is raised when some educators focus resources on teaching students only first-level technology skills, that is, how to work the technology, and neglect to teach the second-level skills of symbolic representation and knowledge integration in which technology is a vehicle for deeper understanding and alternative ways of representing information. Will this mean that some students graduate only with technical skills, while others are equipped to become symbolic analysts and knowledge workers functioning at higher levels in society?

Surveys, Tests, and Resource Allocations What gives districts and states the best information they need to make decisions on which to frame policy? Can surveys about technology use give us equally valuable information for policymaking, at less cost and burden to students and teachers than tests? In one model, used by the Bellingham Public Schools (http://www.bham.wednet.edu/elmankat.htm), students self-report what they can do with computers and multimedia, file management, presentation resources, information searching, and other technology-supported activities. The results are used to derive elementary, middle, and high school technology outcomes.

Research Much needs to be done to better understand how technology skills are best developed, assessed, and supported. There is little agreement on common data elements that could be collected across projects to give a clearer picture of outcomes. Schools and school systems are hungry for assistance in this area—data they should collect, activities they should observe and record, indexes that go beyond test scores, criteria that suggest when to make mid-course adjustments, best practices they can adopt, and models they can emulate. With the substantial investments in technology at all levels, greater funding and dissemination of research will assist educators and policymakers at all levels in implementing technology goals and applications.

CONCLUDING COMMENTS

If teaching with ever-changing technologies is like building an airplane while it is in flight, then defining and assessing what skills are needed to work and learn with technology is akin to developing a flight plan en route. Nonetheless, the reality of today's technological environment means that educators must address the issue of technological fluency for all students. Perhaps what is most exciting and promising is that the demands of technology are forcing educators to have conversations about broad goals for teaching and learning in the twenty-first century. Through these conversations and the policies that evolve from them, America's children may indeed develop the skills and wisdom they will need to meet their dreams.

---

i An excellent summary of this research can be found in "The Effectiveness of Using Technology in K-12 Education: A Preliminary Framework and Review," a report prepared for the U.S. Department of Education by Beatrice F. Birman, Rita J. Kirshstein, Douglas A. Levin, Nancy Matheson, and Maria Stephens (Washington, D.C.: American Instates for Research, January 1997).

ii Reginald Gregoier, R. Bracewell, and T. Laferriere "The Contribution of New Technologies to Learning and Teaching in Elementary and Secondary Schools," a collaboration of Laval University and McGill University, August 1, 1986. (http://www.fse.ulaval.ca/fact/tact/fr/html/impactnt.html)

iii "Synopsis, Computers in American Schools, 1992: An Overview." Report of the IEA Computers in Education Study. University of Minnesota, February 1, 1994.

iv B. Berenfeld, "Linking Students to the Infosphere," *T.H.E. Journal*, April, 1996, pp. 76-82.

v This section draws heavily on conversations with Henry Becker, University of California at Irvine, and his paper "Business Support for American Education: What National Interest Demands, Telecommunications Makes Possible." http://www.gse.uci.edu/VKiosk/Faculty/hank/ReichSCANSColeman.html

vi Secretary's Commission on Achieving Necessary Skills, *What Work Requires of Schools* (Washington, D.C.: U.S. Department of Labor, 1991).

vii Cognition and Technology Group at Vanderbilt, Learning Technology Center, Peabody College, "Looking at Technology in Context: A Framework for Understanding Technology and Education Research," in D.C. Beringer and K.C. Calfee, eds. *Handbook of Educational Psychology* (New York: Simon and Schuster Macmillan, 1996).

viii Barbara Means et. al., *Using Technology to Support Education Reform*. SRI International for U.S. Department of Education (Washington, D.C.: U.S. Government Printing Office, 1993), p. 2.

ix James Bosco, "Schooling and Learning in an Information Society." OTA contractor report, November, 1994, NTIS No. 95-172227.

x National Commission on Excellence in Education, op. cit. fn. 4.

xi MCREL, the Midcontinent Regional Education Laboratory, has assembled these content standards and produced a number of documents useful to educators. See http://www.mcrel.org/standards-benchmarks/doc/contents.html

xii ibid.

xiii Discovery Communications, "Computers: Hype or Hope?" Part of the *School Stories Series* (to air October 12 and December 28, 1997), Discovery Channel (http://school.discovery.com).

xiv For more information, see www.virtual-canyon.org

xv U.S. Congress, Office of Technology Assessment, *Teachers and Technology: Making the Connection*, op. cit., fn 3.

THE MILKEN EXCHANGE ON EDUCATION TECHNOLOGY NATIONAL ADVISORY BOARD

MILKEN FAMILY FOUNDATION

BOARD OF DIRECTORS

Lowell Milken
Michael Milken
Dr. Julius Lesner
Rosey Grier
Harvey Silbert
Ralph Finerman
Lynda Resnick
Thomas J. Kalinske
Lori Milken
Sandra Milken
Ferne Milken
Mariano Guzmán
Murray Hackel
Ellen Sandler
Dr. Thomas C. Boysen
Joni Milken-Noah
Dr. Lewis C. Solmon

PROFESSIONAL STAFF

Lowell Milken
President

Dr. Julius Lesner
Executive Vice President

Dr. Thomas C. Boysen
Senior Vice President, Education

Dr. Lewis C. Solmon
Senior Vice President, Senior Scholar

Lawrence Lesser
Senior Vice President, Production

Ralph Finerman
Senior Vice President and Treasurer

Joan Brooks
Vice President, Milken Family Foundation National Educator Awards

Dr. Cheryl Fagnano
Vice President, Education Research and Programs

Cheryl Lemke
Vice President, Education Technology

Christopher M. Crain
Vice President and General Counsel

Katherine Nouri Hughes
Vice President, Communications

Michael Reese
Vice President, Government and Public Affairs

Ian Noah
Vice President, Mike's Math Club

Joni Milken-Noah
Vice President, Mike's Math Club

Steven J. Cobb
Chief Financial Officer

Barbara Klein
Program Director, Festival for Youth

Dahlia Geilman
Program Administrator, Grants

Rosey Grier
Program Administrator, Community Affairs

Rebecca Rona
Program Administrator, Music Archive

Tamara Schiff
Education Research Associate

MILKEN FAMILY FOUNDATION

Milken Exchange on Education Technology
1250 Fourth Street
Santa Monica, California 90401-1353
(310) 998-2825 telephone
(310) 998-2899 facsimile
e-mail: clemke@mff.org
Web site: www.mff.org

NOTICE

REPRODUCTION BASIS

☒ This document is covered by a signed "Reproduction Release (Blanket) form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

☐ This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").