News & Comment

Computers Make Slow Progress in Class

The high-tech transformation of education that some were predicting a few years ago has not happened. Experts battle over what role computers should play

FOUR YEARS AGO, a task force assembled by then–secretary of education Terrell Bell produced a report that intoned: "Just as the automobile has transformed American society beyond the expectations of its originators," so will the use of educational technology "lead to the transformation" of public education.

That report was never published by Bell's successor, William Bennett. Perhaps that's just as well, since its confident prediction appears to have missed the mark. Although there are now an estimated 1.5 million computers in the public schools—one for every 30 kids—nowhere can they be said to have transformed education. Nor, research suggests, does teaching children how to use and program computers stimulate the development of sophisticated general thinking abilities.

The fact is, after more than two decades of research, the task of successfully integrating computer technology into regular instruction still appears daunting. It is considerably more complex than was envisioned as recently as 1983, when an earlier report issued by Bell's department, "A Nation at Risk," touched off the current wave of educational reform.

What happened? Even many computer enthusiasts say the expectations were overblown. Some, like Alan Kay of Apple Computer, complain that parents and teachers want to regard computers as "the latest magic salve" for education's ills. They say there is too much focus on the computer as an end in itself rather than as a means to facilitate the real goal: radical change in the way children are educated.

There has certainly been no shortage of vision. Indeed, the literature is rampant with enthusiastic scenarios about students discovering facts on their own, collecting and analyzing data, and putting together scientific projects—collaborative and individual—with the aid of sophisticated "cognitive tools," vast data banks, exciting graphics, interactive video, dynamic simulations, and telecommunications. Researchers see computers as helping to free students from rote learning tasks and promoting the use of creative and abstract thinking abilities in conjunction with even elementary language and math skills. They see "intelligent tutors" as introducing students to concepts they would not otherwise be exposed to. They envision teachers being freed from tiresome logistical tasks so they can lead discussions of ideas.

And some of these very things have begun

Here and There, a Few Bold Experiments

Computers are finding their way into more and more classrooms, but they are mostly being used in traditional ways: drill and practice in math in elementary schools and programming in high schools. But a growing number of more innovative approaches are being pursued in isolated experiments here and there.

- Perhaps the most extensive one now under way is Apple Computer's "Apple Classrooms of Tomorrow" (ACOT). This entails long-term studies on what Apple calls HCA or "high computer access" environments in two dozen classrooms around the country. All students have computers for both home and school use. Programs range from individualized reading and language skills for "at-risk" students to an interdisciplinary curriculum at an Ohio high school using robotics, interactive video, digitized music, and hypermedia. Kids have used computers to design a scale model of downtown Columbus, complete with little robotic cars, lights, elevators, and construction machinery.

Some researchers are skeptical of ACOT, saying it lacks a guiding philosophy and amounts to nothing more than "saturation" of schools with computers. Apple has recently decided to supplement this "laissez-faire" approach with a series of research and development studies, such as a high school physics tutoring program, that analyze the interaction of teachers, students, and technology.

- Hennigan Elementary School in Cambridge, Massachusetts, where, according to Mitchell Resnick of the Massachusetts Institute of Technology, the general thrust is to "create a new type of learning culture" with the aid of Logo, a programming language developed for children by MIT's Seymour Papert. The 250 children in grades 2 through 5 work daily with 100 computers arranged in common areas called "pods." They do science and math projects and create stories with the aid of a word processing program, graphics, and animation. The latest twist is LEGO-Logo, in which the students make up programs to assemble building blocks and operate gears, wheels, and motors using LEGO construction toys.

- The Los Angeles Open Magnet School, where 250 students of varying backgrounds, who were chosen by lot, work in five large classrooms with 20 computers in each. Monitors are visible under Plexiglass working surfaces, and students are encouraged

One of GTE's SmartClassrooms.

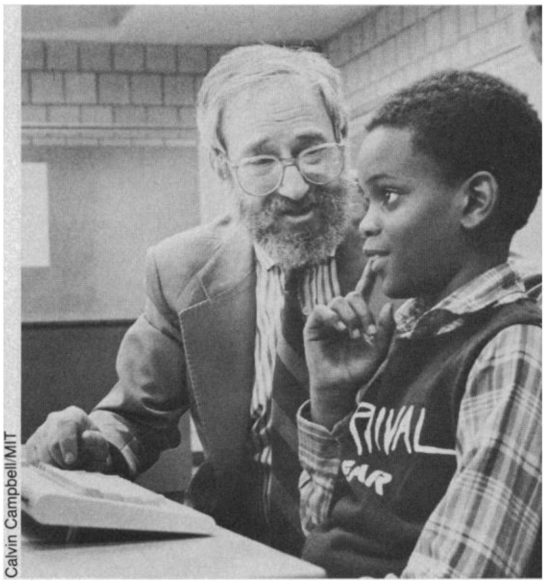
to happen in a few classrooms around the country. Based on weeks of interviews with dozens of education reformers and computer experts, *Science* has compiled a few examples of schools where experiments are going on that particularly intrigue educators (see box). Here and there across the nation, some kids are making computer models of cities and designing fantasy animals and their environments; compiling databases of local weather statistics and sharing the information via telecommunications with students at other schools in the United States and abroad; solving everyday problems in thermodynamics; and even working out complex astronomical equations on a supercomputer.

But experimental programs scattered helter skelter across the landscape will not transform American education. Robert Tinker of the Technology Education Research Center (TERC) in Cambridge, Massachusetts, warns, for example, that although everyone can provide euphoric descriptions of their own programs, there is often less than meets the eye. Many are guided by no particular educational philosophy, and the results, he says, are "no more educational than the local electronics surplus store."

The obstacles are many. For one, there is no widely accepted model for how to use computers. The experts are divided over the role that computers should play in the classrooms, reflecting divisions over educational strategy. And there is a big gap between the theorists and those on the front lines in the classrooms.

Then there are more practical problems: these many years into the computer age, teachers still have little training in computer use, much less how to choose and employ software productively. Most teachers are women, who are less likely than men to feel comfortable with computers, at least in the ways they are most commonly used. The vast bulk of educational software is uninspiring, and manufacturers are in a bind because few have had success in marketing innovative products.

According to Marcia Linn of the School of Education at the University of California in Berkeley, there has been a "backlash" in some places following misguided enthusiasm in the early 1980s when many school districts eagerly piled up computers from whatever sources they could muster, from corporate gifts to proceeds from bake sales. Although teachers are generally said to be interested in the technology, many have been burned by having computers "dumped in their lap" with no guidance as to their use, says Linn. Indeed, one thing that has become clear is that, far from making teachers unnecessary, the intelligent integration of technology requires them to rethink their roles and constitutes a major challenge to their flexibility and ingenuity. Then there have been technical problems—some schools did not even provide money for maintenance—and unfortunate experiences


Calvin Campbell/MIT

Seymour Papert: *Argues that children should be "put in charge" of their own learning.*

to use them whenever appropriate, as a "medium" like paper rather than a "tool," according to Alan Kay of Apple. Kay is codesigner of a special research project called "Vivarium" in which students design their own fantasy animals, complete with behavioral characteristics, and their living environments. The ultimate purpose of the project is to explore "intuitive thinking" that can be exploited in the development of future software.

■ A Harlem elementary school has a 40-computer lab and a local area network called Earth Lab, which has a database, word processor, and geography software. Every morning a group goes up to the roof with instructor Paul Reese to collect data on rainfall, temperature, pressure, wind direction, and cloud cover which they then enter into computers. They also exchange data and do joint projects via telecommunications with a school in London. Students are free to use computers before classes and at lunchtime for other projects.

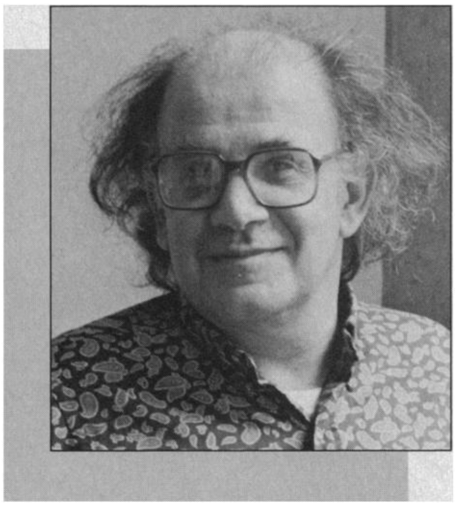
■ The Thomas Jefferson Magnet School for Science and Technology in Fairfax County, Virginia, has 40 students doing projects on a supercomputer it won in a contest sponsored by Control Data Corp. Among the projects are an investigation of "Paths of convergence to the roots of unity by the Newton-Rathson method" (a graduate-level math problem) and "Development and application of chaotic techniques for the analysis of multi-differential systems" (a characterization of the behavior of a planet tugged by two stars). All the students working on the project are boys; the school itself is two-thirds male.

■ The National Geographic and the Technology Education Research Center (TERC) in Cambridge, Massachusetts, have developed "Kidsnet," a telecommunications network linked to 1000 classrooms around the country. There is software covering five different units, such as weather or acid rain. Students do fieldwork and analyze and share their data with other schools. Linkage to the scientific community is provided by a central clearinghouse to receive and give feedback on the information generated. Each unit has a scientist adviser (for acid rain, it's John Miller of the National Oceanic and Atmospheric Administration).

■ At Foothills Middle School in Walnut Creek, California, Berkeley researchers, Apple, and NSF are contributing to an 8th-grade science program where computers are used as "silent lab partners." Students using Macintosh computers to do real-time data collection and simulations of problems involving thermodynamics. Working in groups, they pose practical problems, such as what is the best wrapping for keeping a potato hot and a comparison of cooling rates for different volumes of water.

■ GTE California has built "the world's only two 'SmartClassrooms'" for 7th-grade science classes. According to GTE spokesman Larry Cox, they combine "a variety of what used to be thought of as incongruous technologies," including robotics, laser discs, four-color video, CD-ROM (compact disc read-only memory), and satellite communications linked to a weather station, as well as "literally everything" in the way of instructional software. One of the classrooms at E. O. Green Junior High in Oxnard, California, has been remodeled and furnished with 36 computers (one per student) at a cost of $220,000. The second classroom, at Blackstock Junior High School has, in addition, a "master control unit" which provides computerized testing, diagnosis, and remedial instruction. GTE aims to expand the project to other areas and to make the entire school district a "smart district."

■ C.H.



Janine Nichipor

"Salvation is not going to come from ubiquitous interactive video discs and artificial intelligence."

—Judah Schwartz

with poor quality software.

If individual school districts are struggling to get into the computer age, why is the federal government not providing any help? The short answer, according to a 1988 report by the Office of Technology Assessment (OTA), is that federal research policy has been "erratic and disorganized" since the Education Department's short-lived technology initiative collapsed with the departure of Terrell Bell. There is no lead agency for educational technology and very little coordination among relevant agencies.

The Department of Defense has the most money for this type of research, but its activities are directed toward improving military training and there is little spin-off for public education. The National Science Foundation (NSF) funds the development of advanced software, but no federal agency funds any classroom-based demonstration programs. As for the Education Department, "Bell called for a 'Manhattan [Project]' approach to educational technology—we don't even have a match," says Frank Withrow of the Office of Educational Research and Improvement.

The department, in fact, is supporting only one classroom-based research program—a $1-million-a-year effort run by the Center on Technology in Education at New York's Bank Street College of Education. Says the OTA, Bank Street is now "the only game in town."

Until last year, Harvard held that honor. It managed the department's lone educational technology center, receiving $7.6 million for a 5-year contract, which it spent doing fairly narrowly focused research on several pieces of educational software. It concentrated on specific obstacles to learning in math and science.

When Harvard's contract expired, the Department of Education decided it wanted to broaden the effort but spend less money. It wanted even more emphasis on applied research and coverage of a wide range of curriculum content. It also added assessment of student performance and analyses of the "efficiency and productivity" of various approaches. Harvard decided not to apply—"we were already being stretched too thin," says Judah Schwartz of the Harvard center.

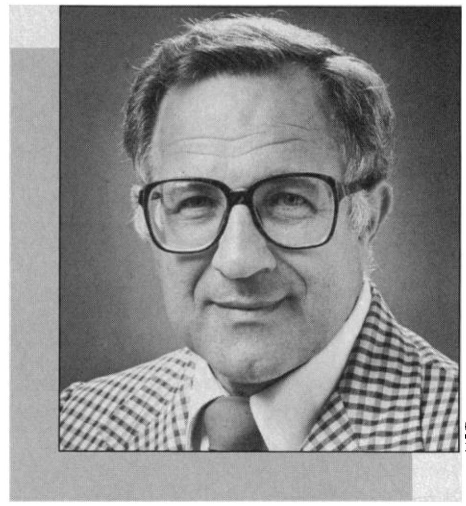
Bank Street has a federal mandate to concentrate on the development of what it calls a "design science" of education. Over the next few years it intends to put together a half-dozen "design experiments" in selected schools, planned in collaboration with the teachers.

The Bank Street people say that if there is a "school of the future" anywhere that stands as a model to strive for, they do not know about it. They hope to remedy this by developing a variety of models and a systematic way to evaluate them. Bank Street's approach is "more practical than theoretical," says Jan Hawkins, associate director of the new center.

But if the past is any guide, Bank Street may have a hard time convincing others of what the optimal strategies are, for the field of educational technology is shot through with disagreements that are rooted in conflicting notions of educational reform.

To start with, "there is a vast gulf" between cognitive psychologists and developers of advanced software, on the one hand, and teachers on the other, says Henry J. Becker of Johns Hopkins University, who has been conducting national surveys on computer use in the public schools. The big thinkers, he says, are driven by theories based on the past 20 years of cognitive science research: that people learn new things by attaching them to things they already know; that knowledge must be presented in meaningful contexts; that learning is active, not passive; that individuals have different learning styles.

These ideas, which have been around since the turn of the century, are now being presented in a shower of new (and not-so-new) buzz phrases: "student empowerment," "teaching for understanding," and "activity-based," "inquiry-driven," "discovery-based," "child-centered," "hands-on," and "minds-on" learning. All of this is supposed to lead not to learning more but learning better and the cultivation of what seems to be the grail of modern educational theory: "higher order thinking skills."



NSF

"The constructionist environment is very inefficient, and in many cases almost nonproductive."

—Andrew Molnar

But most teachers, says Becker, want technology that will fit into the traditional curriculum. They are not into cognitive psychology. Most are still basically immured in the behaviorist paradigm that guided the earliest attempts at computer-aided instruction: the instructor presents the stimulus, the students respond, and are given feedback on whether they are right or wrong. Or, in Kay's metaphor, teachers treat "knowledge as fluid" which pour into the student-vessels. Many reformers seem so contemptuous of this model that they make it sound like child abuse. Says Kay: "most schools are close to psychological murder on children."

The theorists are critical not only of the practitioners. They often do not see eye-to-eye with each other. One way of characterizing the differences of opinion, according to John Anderson of Carnegie-Mellon University, is "the degree to which one views learning experience as self-directed versus prescriptive." The latter tend to be less idealistic about the prospects for dramatic changes in education and instead look for ways to make it more efficient.

The differing implications for technology are illustrated by two pieces of geometry software. One is the "Geometric Supposer" developed by Judah Schwartz of Massachusetts Institute of Technology for elementary school use. The program, he says, has "no pedagogical agenda" and does not dispense facts. Rather, it offers a structure to guide the student's own discovery of rules and theorems. Schwartz's metaphor for the program is an "intellectual mirror" which is flexible enough for the student to find out through experimentation what works and what doesn't.

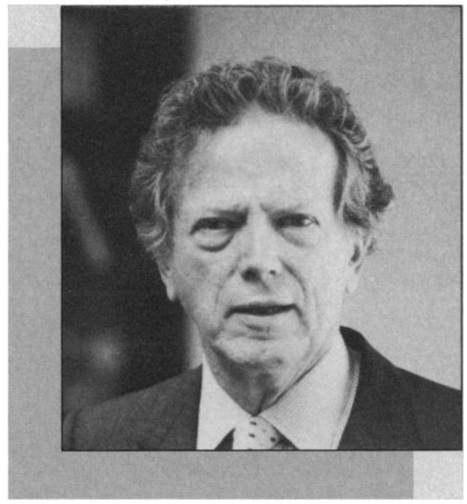
Anderson's "Geometry Tutor," developed for high-school students and modeled on human tutors, has entirely different goals. This is an "intelligent tutoring system" with an enormous storage capacity that offers, step by step, concepts and problems illustrating them. It progresses to the next concept only after the student has mastered the current one. It gives continuous feedback, and when the student makes a mistake the tutor figures out what is needed to get him back on a correct path. While tutors are technologically advanced, Schwartz sees them as regressive in concept—he dismisses the Geometry Tutor as "totally didactic and normative."

The "self-directed" people, such as Schwartz, are sometimes called "constructionists"—a reference to the doctrine that students do not learn by having information poured into them but "construct" their own knowledge. They tend to see major educational reform as essential for the intelligent use of technology. Robert Tinker of TERC, for example, calls himself a "dyed-in-the-wool constructionist." Says he: "If education were oriented toward empowering kids" instead of "teaching facts and formulas," computers "would be all over the place." Tinker opposes the prescriptive approach as requiring a "highly structured learning environment." This, he says, "just doesn't get at the tough things—problem solving, independence of thought, collaboration."

Seymour Papert of MIT has been identified as the ultimate representative of the self-directed school of thought. He holds that children, being the bright, creative, and curious creatures they are, will develop their natural abilities best if "put in charge" of their own learning—that is, given a loosely structured environment that includes flexible tools allowing them to construct their own approaches.

Schwartz is regarded by some as a more pragmatic advocate of the constructionist approach. He is leery of elaborate high-tech scenarios and says research should be focused on exploiting the potentials of currently available technology. "Salvation is not going to come from ubiquitous interactive video discs and artificial intelligence. Salvation is going to come from different attitudes toward learning and technology."

Similarly, Michael Cole of the Laboratory of Comparative Human Cognition at the University of California in San Diego believes too many educational technology researchers have a "go for the moon" approach which focuses on the "object" (the



"Discovery-based learning" is "all idle talk . . . second-order talk by people who like to deal in abstractions."

—Partick Suppes

computer) rather than where it belongs—on "the organization around the object." Says Cole: "We need to create powerful environments."

Many of the more radical thinkers tend to de-emphasize technology's role in educational reform. In contrast to the early days, few people now believe it has the power to transform education. Rather, as Linn puts it, computers are seen as "catalysts" for change. Kay of Apple goes even further: "I don't think education can be revamped unless we can revamp it *without* resorting to technology."

Traditional cognitive scientists agree with everyone else that education is in bad shape, and they generally go along with the constructionists in urging deeper understanding of concepts and a "hands-on" approach to learning. But they do not necessarily think that radical reform of education is the sine qua non for productive use of technology. For one thing, says Andrew Molnar, director of NSF's program for Advanced Applications of Technology, it is clear that society is not willing to make the necessary investment. "So you have to look at technology as an alternative."

Molnar sees particular promise in technologies still under development, such as intelligent tutors, which are designed to convey the content of an entire course without a teacher, and "visual representations" of complex and unseeable concepts—such as black holes, chaos, fractals, quantum mechanics—that can be explored experientially.

Molnar criticizes constructionism as "a school of thought that 'I can't teach you anything, you have to learn yourself.' " That is all very well when you have bright graduate students and highly motivated teachers, he says. But otherwise, "the constructionist environment is very inefficient and in many cases almost nonproductive."

Patrick Suppes of Stanford University, who is developing an intelligent calculus tutoring program, is also skeptical. He is highly critical of the "romanticism" that pervades much current thinking. While cognitive science has produced "a lot of particular things," he says, there are few experimental data to justify the leap to many prevailing assumptions.

He says, for instance, that there is no evidence whatsoever that "discovery-based" learning—which he equates with the dubious "open classroom" experiments of the 1960s—is superior to more prescriptive approaches. "What are you going to do, rediscover the wheel?" In his opinion, "it's all idle talk . . . second-order talk by people who like to deal in abstractions. It's romanticism until somebody produces a sufficiently articulated, detailed theory that is based on a large body of data."

Suppes doesn't think there is any particular reason to believe that an educational revolution is in the offing—"People have been talking that way since Dewey opened his first experimental school at the University of Chicago in 1890." Rather, for the foreseeable future, schools will continue to adopt the most common models, such as computer labs for practice in math and language skills. Within the next couple of decades, he believes, intelligent tutors will be teaching advanced high school science courses that otherwise are not available because of the shortage of trained teachers.

Evaluation of the different approaches now being explored is only beginning to be addressed in research, and it presents an enormous challenge, since there are no instruments to provide a uniform standard of comparison.

Computers will unquestionably become an integral part of precollege education, if only because they are increasingly a fact of life everywhere else. But how, when, and whether the incredibly rich potentials offered by new technologies will be realized remains a mystery. Many educators, as the OTA report notes, "fear that without major restructuring of schools . . . no significant changes will or can be made, with or without technology R&D." But changes there will be, and it is likely that the impact of technology on schools will ultimately be manifested in ways far more subtle and varied than anyone can now predict.

■ CONSTANCE HOLDEN