SYMPOSIUM: The Future of Computers in Education

The Likely Evolution of Computer Use in Schools

Students of the future will be "trained" by computers and "educated" by teachers, allowing both computer and teacher to function in more efficient and cost-effective ways.

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During the next decade, schools will gradually shift from a teaching/learning model based almost exclusively on human instruction to a new approach that combines teachers and machines. This shift will be driven by financial pressures on schools and America's desire to have a workforce capable of competing in the increasingly automated international marketplace. The speed of this transformation will depend on (1) how quickly America moves to a knowledge-based economy, (2) how much educators resist changing their occupational roles and organizational structures, and (3) how many resources society commits to producing quality instructional courseware and to retraining teachers and administrators.

This article depicts the probable characteristics of the new model for machine-mediated learning, the ways in which the present curriculum will alter, and the stages by which the transformation will take place.

Emerging Capabilities for New Methods of Instruction

As the information technologies continue to increase in power while dropping in cost, the range of teaching functions they can perform at a price schools can afford is growing very quickly. Between now and the end of this decade, developments in the speed, memory, power, and price of the information technologies will create a wide range of new educational modalities. Those modalities will include hand-held, desktop, and larger computers; computer networks; mass telecommunications; and interactive videodiscs. Together, they will provide the opportunity to transfer to machines many functions of teachers.

Within this decade, technological advances will have the potential to:

1. Improve instruction in conventional subjects
2. Allow the efficient teaching of types of knowledge and skills previously too expensive to include in the curriculum (such as sophisticated laboratory procedures and advanced music)
3. Improve research into the teaching/learning process
4. Expand the number of students per teacher without inreasing costs or decreasing quality.

Much of the material now laboriously taught through group use of textbooks and rote exercises will be conveyed via hand-held devices. Image a $20 machine the size of a calculator, with a screen covering most of its surface, a few function keys, and a slot in the back for reprogrammable memory chips costing about 50 cents. The student can read a history lesson, controlling the flow of material with the keyboard, then take a test to check assimilation of the material. Simultaneous voice output via an earphone will help build reading and language proficiency.

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A different memory chip and a slightly more sophisticated machine will allow the student access to census data; keyword input gives the information needed to write a paper on historical demographic shifts. While this approach represents no great advance in instructional methods or efficiency, it will cost less than multiple textbooks, allow greater individualization, be more easily updated, use less space, and build student facility in computer use.

Desktop computers will create new types of instruction. Graphics, music, voice output, touch-screen, and voice input will enable the computer to use games, simulations, and "microworlds" to teach sophisticated skills. Such devices can motivate extended student concentration and learning without teacher supervision. The computer will even be able to diagnose the learning style and needs of the individual student and gear instruction to match these characteristics as well as collect data on student learning to aid evaluation and research.

With such sophisticated machines, students will master many types of material much more rapidly than is possible in current classroom settings because the presentation is individualized, highly stimulating, and interactive. Skills similar to those needed in occupational applications of computers will be developed as a useful by-product. Larger computers and other information technology/telecommunication devices have even more advanced educational capabilities.

Coming Changes in Curriculum Content and Design

Of course, even with all these attributes, information technologies will not be as good at instruction as skilled human teachers. While educational devices can simulate phenomena more effectively than a teacher at a blackboard, a trained professional, *working one-on-one*, can facilitate the intellectual and affective growth of a student far better than the most sophisticated and expensive computer.

However, given the amount of money that society chooses to invest in education, classes are too large and teacher salaries too low to make human-mediated learning very effective. Individualized use of computers *can* be far more efficient than underpaid teachers working with students in groups of 20 or more, but only for certain types of subject matter.

Imagine the entire curriculum divided subject by subject into two parts, one called "training" and the other "education." Training incorporates all the material with a limited range of right answers, such as basic math, language decoding, and descriptive science. Education includes the "multiple right answer" portion of the curriculum: creative writing, human relations, critical interpretation, and so on.

Training is done by machines. Defining an incorrect learning response and channeling the student in an appropriate direction are relatively easy to program for a small range of right answers. Since training is best done in an individualized manner with ample learner motivation and immediate reinforcement, these instructional devices are ideal. In fact, sophisticated machines are so good at training that this portion of the curriculum can be taught much faster than is now possible using human teachers and large student groups.

On the other hand, the difficulties and costs of using machines to educate are prohibitive because the task of programming a device to recognize all the alternative right answers is almost impossible. Interpreting complex subject matter requires a detailed, interrelated knowledge of reality that rule-following, symbolic machines—however powerful—do not have. Instructional devices can be useful supplements to the teacher because of their ability to stimulate complex phenomena, but the human instructor can never be replaced in this part of the curriculum.

Evolving schooling toward a teaching/learning model in which machines train and teachers educate can be cost-effective for two reasons. First, both education and training become more efficient. Machines are better at training and can be used on an individual basis in the early portions of teaching a subject when limited right-answer material is predominant. As students progress and content becomes more complex and indeterminate, education then becomes easier as well. The range of group needs that the teacher must meet decreases when each learner has been given the requisite skills and knowledge to tackle more advanced subject matter.

Second, instruction has always been constrained by the cost of information:

- A printed page has about 10,000 bits of information and costs about 3¢
- A colored slide has about 250,000 bits of information and costs about 50¢
- A half-hour motion picture has about 10 billion bits of information and costs about $500
- Organized real world environments such as technical labs and field trips are even richer in the amount of information available, but are also much more expensive.[1]

Historically, the curriculum has tended to emphasize subjects that can be taught primarily by words, symbols, and line drawings because these are cheap ways to convey information. While words and drawings convey descriptive and declarative knowledge, they are not sufficient for teaching complex procedural skills such as laboratory procedures, medical techniques, advanced writing, instrumentation usage, and equipment trouble-shooting (exactly the types of skills that lead to success in the workplace). The new instructional devices, however, are inexpensive and excellent for conveying complex higher order procedural skills.

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In short, our definition of "intelligence" is changing, as it always does during times of technological progress. Students no longer need rote mastery of skills such as long division—even though they need to understand the concept of division and be able to estimate the results of arithmetic calculations—because inexpensive calculators perform this task better. Even as cheap computers become able to do algebraic manipulation and spelling/grammar/syntax checking, the curriculum will shift to emphasize higher-order aspects of intelligence.

Overall, then, the content of the curriculum will become increasingly differentiated into machine-mediated training and human-based education. A growing emphasis on higher-order procedural skills will emerge as this type of knowledge becomes less expensive to teach. Educators will increasingly see their role as a person/tool partnership, with the more boring and mindless parts of teaching delegated to instructional devices while the truly challenging facilitation of learning and growth remains a human-centered process. Because of gains in learning efficiency and

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the ability to serve a larger number of students, teachers salaries will be higher, and more advanced subject matter will be covered in the same time it now takes to teach basic skills.

Stages of Evolution to the New Model

The transformation of schooling to teacher/tool partnerships is essential, given education's growing need to inexpensively prepare students for the knowledge-based economy. However, this new approach has many potential weaknesses, and the transition between models will need careful management to ensure that possible problems are minimized.

For example, a generation of gains in educational equity may be lost within the next decade if the shift to machine-mediated learning is handled without making egalitarian policies a priority. Moreover, unless human interaction and interpersonal skills are emphasized in the education portion of the curriculum, students' affective growth may be stunted by spending so much time with machines rather than people. These and other threats to quality mandate that the gradual transfer of responsibility from teacher to tool be carefully monitored to control unwanted side-effects.[2]

Currently, five types of computer utilization are appearing in schools:

1. Computer-assisted instruction (drill and practice, tutorial, simulation, demonstration, gaming)
2. Computer-managed instruction (testing, diagnosis/prescription, teacher recordkeeping tools)
3. Use of applications programs (word processing, communications, spreadsheets, database management, graphics)
4. Programming (predominantly in BASIC, LOGO, PILOT, PASCAL)
5. Computer literacy (societal implications, demystification).

As sophisticated modalities become available, the balance among items on this list will change.

At present, many districts are focusing their efforts on computer-assisted instruction, where most commercial software is available, and on computer literacy, which requires the least expensive equipment. These two approaches also necessitate less staff training than the other three alternatives. Computer literacy, which has as many definitions as there are practitioners, may gradually be de-emphasized as students automatically acquire this knowledge through their other computer experiences. Computer-assisted instruction is currently limited by the low quality of most courseware; this is unlikely to change until a more certain funding base for these materials develops.

As teachers and students master the simpler skills in using computers, the emphasis in schools will begin to shift to more sophisticated applications. Programs such as word processing and database management will slowly spread from the reading center and business department into many types of courses. Teachers will routinely use authoring languages to modify courseware and gradebook programs to simplify the drudgery of recordkeeping. Programming will move beyond the computer science area to become integral in learning the cognitive map of a variety of subjects.

The most important limitations on the speed and quality with which the transition to this new model proceeds are:

- The willingness of educators to recognize the necessity for change beyond simply adding information technologies as a teacher supplement (which is too expensive to survive as an innovation)
- The amount of funds allocated to staff retraining (since most attempts at educational change have foundered on this point)
- The ability of early courseware to demonstrate the potential usefulness of computers (which has so far been poor, due primarily to a shortage of good ideas and a pervasive uncertainty about the size of the potential market)
- The amount of funding schools can spare from shoring up the present model to purchase equipment and software.

To the extent that educators act collectively to divide the burden of experimentation and to pressure industry, families, communities, vendors, and governments for assistance, these barriers will decrease.

American society as a whole may shrink from the magnitude of change needed to achieve a knowledge-based economy. But this choice will not be without costs, as the recent history of the auto and steel industries attests. The schools may choose to stay with the traditional model, hoping that prosperity will return and that industry will accept the burden of preparing students to use the information technologies. Public education may then become increasingly peripheral to the concerns and priorities of society. Educators may move to teacher/tool partnerships with insufficient attention to side effects, which will create a new set of systemic problems to plague schooling.

The new model discussed here is by no means a guaranteed solution to America's present crises. It does, however, look better than the other realistic alternatives now open to us. Will we have the courage to risk beginning this transformation, the vision to find time and resources when current problems are overwhelming, and the control to regulate use of these tools so that their weaknesses are minimized?□

References

[1]Joseph Lipson, "Riding the Wave of the New Information Technologies: The Administrator's Role," paper presented at EDUCOM Conference, Kansas City, Missouri, October 1981.

[2]Christopher Dede, "The Reshaping of Adult, Career, and Vocational Education by the Emerging Communications Technologies" (Columbus, Ohio: National Center for Research in Vocational Education, Ohio State University, 1983); and "Educational, Social, and Ethical Implications of Technological Innovation," *Programmed Learning and Educational Technology* 18 (November 1981): 204–213.

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