The Role of Computer Technology in Restructuring Schools

by Allan Collins

Most work in the U.S. is becoming computer-based, and the nature of schoolwork will make a parallel shift, Mr. Collins predicts. The outcome is likely to be a more constructivist view of education.

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In a society where most work is becoming computer-based, school work cannot forever resist the change. Computer technology and electronic networks have slowly been infiltrating the schools.[1] Because of the widespread and growing use of such technology in both the home and the workplace, computer equipment is unlikely to end up in closets or even to sit idle most of the time. Hence, for both students and teachers, there is a kind of "authenticity" associated with using this equipment; for students, the technology represents the future.[2]

When a technological innovation - be it the book, the automobile, or television - becomes widely available, its ramifications spread throughout the society, and that includes education. For example, the invention of the printing press - and with it the advent of affordable books - had profound effects on education.[3] It made the ideas of universal literacy and public schooling possible and led to a de-emphasis on teaching the art of memory. The automobile - and the bus - led to the consolidation of rural schools, the dispersion of people to the suburbs, the split between urban and suburban education, and the practice of busing to achieve racial integration. The impact of television and video technology on education is already evident in the decline of the print culture and the rise of a visual culture, in shorter attention spans, and in a loss of innocence among children.[4] Similarly, the computer and the electronic network are likely to have significant effects on education, and it behooves us to consider what those effects might be as we think about the issue of restructuring schools.

TWO VIEWS of education have been at war for centuries: the didactic (or information transmission) view and the constructivist view.[5] The didactic view prevails among the general public. It holds that teachers should be masters of particular domains of knowledge and that their job is to transmit their expertise about these domains to students through lectures and recitations. Students should memorize the facts and concepts of the domain and practice its skills until they have mastered them, and they should be able to demonstrate that mastery on appropriate tests.

The constructivist view, which under girds the work of John Dewey, Lev Vygotsky, and Maria Montessori, holds that teachers should be facilitators who help students construct their own understandings and capabilities in carrying out challenging tasks. This view puts the emphasis on the activity of the student rather than on that of the teacher. Despite its predominance in the leading schools of education the constructivist view has made little headway in penetrating public education in America or, more generally, in the world at large. But the trends I describe below may change that.

Computer technology can be used in the classroom in three ways: 1) as tools such as word processors, spreadsheets, programming languages, and electronic network systems; 2) as integrated learning systems that present exercises for students to work on individually and that keep records of student progress for reporting to the teacher;[7] and 3) as simulations and games that engage students in computer-based activities designed to be motivating and educational. My argument in this article is that integrated learning systems and simulations (though important for educational

purposes) will penetrate schools only to the degree that the need for tools provides a rationale for buying computers. So the trends discussed below assume the use of computers as tools, though they apply to other uses as well.

It is obviously difficult to anticipate all the effects of computer technologies, and it may well be that I will overlook some of the most important ones. But researchers have begun to observe the impact of these new technologies on the schools, so we can at least make some informed speculations. There are a minimum of eight major trends that can be identified from the literature and from observations in schools that have adopted computers.

1. A shift from whole-class to small-group instruction. When teachers use computers, one or two students are normally assigned to each computer. Teachers do not find it feasible to maintain all the students in lockstep, and so they move to an individualized model of teaching. In their study of Apple Classroom of Tomorrow (ACOT) classrooms, Maryle Gearhart and her associates report a dramatic decrease in teacher-led activities (from constituting over 70 % of class time when computers are not in use to constituting less than 10% when computers are in use) and a corresponding increase in independent or cooperative activities.[9] This shift means that teachers begin to talk to individual students and to develop an idea of how much students understand and what their confusions are. Usually teachers have an inflated idea of how much their students understand, so watching individual students' struggle with problems may give teachers a more realistic picture of their students. The use of computers also means that students are more likely to go at their own pace - and often in their own direction - which can create problems of control for teachers. [10]

2. A shift from lecture and recitation to coaching. As part of the shift from whole-class to individualized instruction, there is a shift from didactic approaches to a constructivist approach. Janet Schofield and David Verban document this shift in terms of language: teachers switch from second-person constructions ("You should do ") to first-person constructions ("Let's try this"). Gearhart and her colleagues found that, in ACOT classrooms, activities *facilitated* - as opposed to *directed* - by teachers increased from about 20 % of class time to 50 %. The introduction of a third party, the computer, into the situation encourages the teacher to play the role of a coach, in much the same way that a piano encourages the teacher to play the role of a coach in a piano lesson. Much of the learning is meant to take place between the student and the computer, so the teacher becomes an observer and a guide who ensures that those interactions are beneficial to the students' learning.

3. A shift from working with better students to working with weaker students. In whole-class instruction, teachers carry on a dialogue with their better students.[11] This is because it is the better students who raise their hands to offer ideas. Teachers do not like to call on weaker students, because they do not want to "embarrass them in front of the class." In a classroom in which students are working on computers, the teacher is naturally drawn to students who need help, and those students are generally the weaker ones. Schofield and Verban document that, in one classroom with individual computers, two of the weaker students received four to five times as much attention from the teacher as the more advanced students. We see this same shift in the classrooms we have observed in New York City and Cambridge, Massachusetts. However, as Schofield points out, there may be a tendency for the teacher to overlook students who need help but do not ask for it, because the teacher is usually very busy in these classrooms.[12]

4. A shift toward more engaged students. In settings in which computers have been put at the disposal of students as part of some long-term activity or project, researchers have reported dramatic increases in students' engagement.[13] For example, Sharon Carver found that students who are so bored with their classes that they sleep through them are eagerly engaged in a project to construct a HyperCard museum exhibit about their city. Similarly, Schofield and Verban report that students compare how far along they are in the geometry curriculum and even fight over who gets to use the computer during the time between classes. David Dwyer, Cathy Ringstaff, and Judy Sandholtz cite several examples of teachers in ACOT classrooms who were encouraged to assign more activities on computers because students were so highly engaged during such activities.[14] It may be that the reported increases in engagement are due to the novelty of the computer, but it is unlikely that this factor accounts for the entire increase. To the degree that the computer supports long-term effort rather than short exercises, there is suggestive evidence from these studies that students become invested in the activities they carry out on computers.

5. A shift from assessment based on test performance to assessment based on products, progress, and effort.
Assessment in most classes is based on students' performance on tests that are given after different sections of the

curriculum have been completed. The introduction of computer technology and the shift to individualized instruction move assessment away from the classroom test, which seems inappropriate to teachers under the circumstances. Schofield and Verban report that, in the geometry class they studied, the computer system would not let the students go on until they had solved each problem. Thus the teacher moved toward assessing students in terms of the effort and progress they made. When the teacher sets up a project-based curriculum, evaluation of students tends to be based on the products that emerge from their efforts. But for the present this creates problems for many teachers, because they do not know how to assess such products objectively. This problem has been solved for writing assessment in terms of holistic and primary trait scoring methods, and clearly some such scheme is needed for project-based work. [15]

6. A shift from a competitive to a cooperative social structure. In the normal classroom, students work individually and compete against one another for grades, except when students drop out of the competition because of social pressures or repeated failure. A number of researchers have found a shift toward a more cooperative social structure in classrooms in which a network provides a common database for students.[16] Marlene Scardamalia and her colleagues describe how students comment on one anothers notes, telling what they find interesting and what they cannot understand. Dwyer, Ringstaff, and Sandholtz note striking increases in cooperative behavior in ACOT classrooms, as reported from the teachers' journals they collected. Geuhart and her colleagues observed that, when computers were introduced into mathematics classrooms, instances of cooperative behavior increased from 10% of the time to 40% of the time, but they observed essentially no cooperative behavior in language arts classrooms, either with or without computers. Even Idit Harel, who studied fourth-graders working independently to produce a Logo program to teach fractions to third-graders, found students sharing ideas and expertise on how to accomplish certain things in Logo.[17] However, Schofield and Verban found an increase in competition in the geometry classroom they studied, and it may well be that integrated learning systems generally encourage students to compete to get through the material faster. A study conducted in Israel suggests that the degree of competition depends on how easy the program makes it for students to compare their progress.[18]

7. A shift from all students learning the same things to different students learning different things. An underlying assumption of the education system is that every student must acquire certain basic knowledge and skills. This assumption leads to failing students who haven't mastered parts of the curriculum and directing students' efforts toward their weaknesses rather than their strengths.[19] Electronic networks and shared databases foster a different view of knowledge in which expertise is spread among different participants and brought together in a common space.[20] The National Geographic Kids' Network, which enables students all over the country to collect scientific data and to exchange ideas with one another and with working scientists, is an embodiment of this idea of distributed knowledge.[21]

Because of the trends toward individualized education, there is likely to be a secondary trend toward breaking the lockstep pattern of everyone learning the same thing in the same way at the same time. This secondary trend

can be seen in the classrooms described by Dwyer, Ringstaff, and Sandholtz, in which students worked on different parts of complex projects, such as a model of their city; in the classroom described by Carver, in which students studied different aspects of their city to develop a museum exhibit; in the classrooms described by Scardamalia and her colleagues, in which students conducted research on different social studies and science topics; and in the school described by Denis Newman, in which students collected different data on the weather.

8. A shift from the primacy of verbal thinking to the integration of visual and verbal thinking. As Neil Postman has argued, the invention of the book took society from concrete, situated thinking to abstract, logical thinking.[22] The visual media - television, film, and computers - have begun to bring about a new kind of visual thinking, and a number of educators are exploring how to use visual media to enhance learning.[23] Computers and electronic networks potentially provide instant access to the world's accumulated knowledge, in both verbal and visual forms. This development may slowly undermine the primacy of the book, the lecture, and their accouterments, such as the multiple-choice test and the recitation class.

These eight trends are subversive to some of society's most deeply held beliefs and assumptions about education. In particular they make tenuous the view that the teacher's job is to impart expertise to the students and that the role of assessment is to determine whether students have acquired that expertise. So, inadvertently, technology seems to be coming down on the side of the constructivists, who have been trying - unsuccessfully to date - to change the prevailing societal view of education.

RESISTANCE TO TECHNOLOGY

David Cohen and Larry Cuban have argued persuasively that computer technology is likely to have little effect on the schools.[24] They maintain that, to the degree that technology is flexible, it will be bent to fit existing practice and that, to the degree it cannot be bent to fit existing practice, it will not be used. People interested in restructuring schools need to understand the various kinds of resistance to change, some of which are specific to technology and some of which are general, in order to identify the key leverage points for changing a well entrenched system.

Any restructuring of schools can take place only over an extended period of time. Hundreds of years after its invention, the printing press was still affecting the development of public education. So I will take a long-term view of how restructuring might come about and in which areas a sustained effort is worthwhile.

If we look at the long term, issues that are currently important - the costs of computer technology, its unreliability, and teachers unfamiliarity with its use - become non-issues. The costs continue to fall - a trend that can only accelerate as computers become more integral to everything we do. It is a fundamental principle of economics that, in relative terms, the cost of goods decreases and the cost of labor increases, so that, compared to teachers' salaries, computers will appear incredibly cheap in the next century.[25]

The problem of teachers' lack of experience with computers will also diminish as people come to rely on computers for writing, calculating, and communicating. This is already happening. It is easier to type into a word processor than to write by hand. (Indeed it is hard to believe that we will continue to put children through the agony of learning handwriting, other than printing, when word processing is so much easier.) It is easier to do taxes on a computer than to do them by hand. And it is easier to send electronic mail than to post a letter. These uses will become commonplace among college students, secretaries, and bookkeepers, so there will be every reason to believe they will become commonplace among teachers. The problem of dealing with computers, such as getting them fixed, will become minor when the machines are used as a matter of course.

But the resolution of these kinds of problems does not necessarily mean that computers will be used in schools. Television is pervasive in society and will probably never be widely used in schools. So why should computers come to be widely used when television is not? My answer is that the computer's most common uses, which are related to work, are becoming necessary to accomplish school goals. Schools are in the business of teaching students how to read and write and calculate and think. As the computer becomes an essential tool for doing things in society at large, its use by students is inevitable. We do not teach people how to drive cars by having them ride bicycles, nor will we

teach people how to do computer-based work by having them use a pencil and paper, arithmetic procedures, and library card catalogs.

There is a related argument that computers make a teacher's job more difficult, just as television and filmstrips or the new science curricula of the 1960's did. The latter required teachers to devote extra time to gathering materials and saddled them with the difficult management problem of coordinating a class of students working independently on experiments or discussing the meaning of what they had done.

It is true that computers make management more difficult when there are only a few computers in a classroom. The teacher has to figure out what to do with the students who are not working on the computers or allow a few who are working on computers to miss a lesson being taught in the meantime. But again, these are only problems in the *transition* to a society in which most work involves computers. If students have ready access to a computer at all times - for example, if everyone has a portable computer that can be connected to a network from different places - then these management problems go away. Students will do much of their work on computers instead of with textbooks or worksheets. The management problem, then, is likely to be similar to the one teachers currently face when students work individually or in small groups. To the degree that the tasks students are doing with computers are more engaging than those they currently carry out with textbooks and worksheets, computers will make the teacher's job easier.

Another argument against the widespread use of computers is that teachers are not willing to relinquish their control of and authority over students. There are two aspects to this argument. One is that teachers want to be masters over everything that comes up in their classrooms, but they will lose authority because computers contain more information than they can possibly master. This situation is currently exacerbated by the fact that teachers do not know a lot about computers - but, as I argued above, that will change as our society becomes more computer literate. The other aspect of the issue of control is that teachers like to hold the attention of their students. If students are off working on their own, then the teacher has lost their attention as well as control over what they are doing. The solution to these problems is to change our view of the teacher's role to that of a facilitator of students' self-directed learning rather than a dispenser of information. Such a change in belief will not come easily and will only come about slowly with the introduction of a great many computers into schools.

Dwyer, Ringstaff, and Sandholtz report that many teachers in ACOT classrooms feel guilty about not teaching the students and nervous about all the talking and sharing of information among the students. These feelings alternate with very positive feelings that the students are highly engaged and actively learning. So ACOT teachers in the initial phases vacillate between enthusiasm for having students do a lot of their work on computers and reversion to their old teaching methods in order to keep the class under control. Dwyer and his colleagues argue that, as the ACOT teachers move toward a more constructivist view of teaching, it is important for them to have the support of other teachers who have worked through or are working through the same transition.

Some people argue that teachers are not capable of using computers effectively. For example, in science labs they usually have students follow a fixed procedure (as opposed to conducting scientific experiments), so that students know at each step what is supposed to happen. Since this procedural approach stems from a desire to make sure all students succeed, it is likely that, when teachers use computers, they will also follow a rigid format. In fact, the computer-based integrated learning systems partially incorporate such an approach.

This argument is surely correct to the degree that teachers can fit computers into their normal way of doing things. But the tools and simulations provided by computers are not content free. They make it possible for students to take over part of their own learning. To the degree that computers support students' autonomous learning - and it is the goal of most educational software designers to provide such support - the particular pedagogical approach of teachers will be less decisive in determining how students learn.

A general view in organization theory is that American schools form a loosely coupled system, and, while they readily adopt changes at the periphery of the system (e.g., model schools, computer labs), it is very difficult to make pervasive changes at the core of the system[26]. While the nature of this system may not be the reason that constructivist teaching methods have failed to penetrate the schools, it will surely slow down any change that is introduced.

Counterposed to the view that schools are a loosely coupled system is the view that American schools have developed a system of institutions - including the age-graded school, multiple-choice testing, curriculum and materials, teacher education, and lecture and recitation methods - that are interlocking and self-sustaining. Disturb any one part of the system, and the other parts will pressure the system to return to its original state. All these

institutions derive from and support a didactic model of education. According to Cuban, this system is characterized by "situationally constrained choice," which operates both within school and classroom structures and within the culture of teaching, including the beliefs of teachers. In his view, these work together to restrict what teachers can do in adopting different innovations.

According to this argument, if you try to introduce computers for students to do their work, the change will be sustained only to the degree that it fits the prevailing institutional structure. Since computers undermine the lecture and recitation methods of teaching and promote the student as self-directed learner, they do not fit this institutional structure and will be squeezed out by it. Integrated learning systems have dealt with this problem by preparing curricular materials that fit easily into the current system. The materials mimic the kinds of test items found in prevailing practice, and so they produce gains on standardized tests.

Integrated learning systems may have some initial success in penetrating schools because they are compatible with the current system. But I contend that it is society's uses of computers as tools that will ultimately sustain their penetration of schools. The interlocking system described can currently slow down the process, but it cannot prevent it, because the nature of education must inevitably adapt to the nature of work in society. (I do not mean to imply that preparation for work is the only, or even the major, purpose of education; other purposes, such as the fostering of citizenship or culture, are also important. But the undeniable importance of education for work means that there should not be a complete mismatch between them.)

Even if technology is allowed into the schools under the guise of reinforcing existing practices, such as drill and practice and multiple-choice testing, once there, it will take on a life of its own. It is important to stress that many of the uses of computers as tools (e.g., word processing, mathematical computation, graphing of data) are quite compatible with current practice. Teachers will not object to students' typing their essays or even, in the long run, to their using computers to solve mathematical problems. Once teachers let computers in the door, then the kinds of effects described in the first section of this article will occur, and teaching practices will change. And just as a change in practices with respect to racial integration led eventually to a change in racial attitudes, [27] so a change in practices will slowly lead to a change in the educational beliefs of the society.

However, the arguments I have made so far suggest only that, over the long run, a change to a more constructivist approach to education is likely to occur. A more salient question is whether there is anything that can be done to speed up the change. In the next section I propose a structural change in school systems that would speed the adoption of any change that would improve educational practice, whether it involves computers or not. And in the final section I address the issue of how technology can most effectively be deployed to foster educational reform.

DESIGNING A SELF-IMPROVING SCHOOL SYSTEM

The present structure of schooling militates against change. Students are assigned to schools and are required to go to them. If the schools are bad, they will continue to exist; there is no way for them to fail. The only thing a school system can do to fix a bad school is to send in a new principal, and usually that person is prevented from making many changes because of the constraints of the situation.

Another problem is that it is difficult to start new schools successfully. It isn't that parents and teachers are prevented from starting new schools, but that incentive is for parents to keep their children in free public schools rather than pay to send them to private schools. So the schools that are started (other than those funded by foundations) tend to be schools for the children of wealthy parents. This is not where our major educational problems lie; they lie particularly among poor and minority populations.

To encourage innovation, we need a system that fosters the creation of new schools and allows failing schools to die, particularly in our large urban areas where the problems of American schools are concentrated. Such a system would stimulate existing schools to do everything possible to ensure their survival. We need incentives and constraints that function to make sure that the most difficult students and problems are dealt with and that natural selection operates on the basis of the quality of the schooling and not on some extraneous basis, such as the race of the principal, the strength of the athletic program, or the endowment of the school with facilities or technology. Any new system especially needs to avoid the current problem of creating schools that serve as dumping grounds for the educationally disadvantaged.

In order to facilitate innovations in schools, I would like to propose the following design principles. They are an attempt to synthesize the essential elements of various proposals for redesigning school systems.[28]

1. *There should be a mechanism whereby a group of parents and teachers in a school district can start a school.* If parents and teachers in a school district want to start a school and if they have a minimum of, say, 25 to 50 students, they should receive from the district at least equal to the current cost per pupil in the district. They should receive space in an existing building that is proportional to the number of students.[29] Since there will be costs associated with starting a school (money for books, technology, and so on), additional start-up financing should come from a special fund, which should also provide resources for the expansion of schools to take on more pupils. In addition, members of the district staff should be assigned to encourage successful schools (either within or outside the district) to set up branches in the district.

2. *There should be a mechanism whereby schools are closed.* If an existing school's enrollment falls below a minimum (say 20 pupils), then the school should be closed and its students forced to choose another school within the system.

3. *A national agency should be established to provide parents and children with information about each school.* To make effective choices, parents and children need to have access to information regarding the educational policy and success of each school - similar to the kind of information available in national guides to colleges. This kind of information is best collected by a national agency, to avoid dishonesty on the part of local officials. The kinds of information the agency might provide include dropout statistics, test scores of students, college entrance and college graduation rates of students from the school, random samples of opinions of former students and their parents, description of the school's operation and facilities by neutral observers, and occupational profiles of former students. All parents and children who will be making a school-choice decision in the future should receive information about all the schools they might consider. In the case of a new school, only a statement of intent would be possible, unless it is a branch of an existing school or a member of a coalition of schools.

4. *Students above a certain age should be provided alternatives to further schooling.* If students of a certain age (for example, 12 years old) wish to drop out of school, then they should be allowed certain options.[30] One option might be to leave school, if they can find full-time employment with a legitimate business enterprise. Another option might be full-time participation in a licensed program, such as a music camp or Boy Scouts. Most important, there should be a national alternative service program, such as VISTA, that would accept any student over the legal age. But students who take one of these options before age 18 should be encouraged each year to enroll in a school of their choice and continue their education. As Peter Drucker argues, we should encourage continuing education - education that goes on throughout one's life - rather than extended education, which keeps one out of the work force through a longer and longer adolescence.[31]

5. *Schools should be allowed to select the students they prefer, but there should be incentives to choose hard-to-place students.* If the proposed system is successful, schools will specialize. This means that their educational programs will probably be more successful for certain kinds of students than for others. It the system restricts schools' ability to select their students, it will restrict their ability to specialize and so undercut a major goal of the plan. On the other hand, all schools may want to accept certain kinds of students and reject others. To offset this tendency, greater financial resources should follow hard-to-place students. In fact, the resources need to be enough greater to offset the systematic preferences of schools, which suggests some kind of market medium.

These five principles are designed to create a system that includes both individual schools and coalitions of schools with specialized goals. There might be technology-based schools, art schools, Montessori schools, essential schools, college-preparatory schools, special schools for disabled children, vocational schools, schools for girls, schools of design and engineering, schools for gifted students in particular fields, back-to-basics schools, schools for particular minorities, bilingual schools, and even comprehensive schools that avoid specialization.

This scene runs counter to the philosophy of having every kind of student in every school to foster the overall integration of society. I would argue that specialized schools should be restricted from discrimination the same way colleges and businesses are restricted. In fact, any such specialized system would spawn a variety of regulations, such as the ones colleges are required to meet to be licensed by the state. But to the degree that schools want to cater to

students with particular interests or abilities, they may develop techniques that are particularly effective. The economic argument for the benefits of specialization applies as much to schools as to business and labor. The moral argument against specialization loses force, given the inevitable disparity between urban and suburban school systems and the widespread tracking already in place in comprehensive schools.

One might argue that most parents and students will pick schools on the basis of proximity, or on the strength of the athletic program, or on the quality of the facilities, even if you provide them with information to make choices on the basis of educational quality. It is certainly true that most people will make their choices partly for such reasons. But most people make choices on the basis of multiple factors, so educational values are likely to play a role in their decisions. The effect of proximity could be diminished by having multiple schools in each building, so that choices could be made among equidistant schools. The effect of athletics could be diminished if we eliminated interschool athletic competition (as opposed to intraschool competition) in favor of Little Leagues or professional sports programs. The effect of facilities would be diminished if we equalized the distribution of resources on a per pupil basis as proposed in the first principle. To the degree that school effectiveness is weighed by people's choices, it will bring a gradual improvement in the quality of the schools. The more it is weighed, the faster the improvement.

Such a plan does not assume that parents know what is best for their children. There will undoubtedly be schools that emphasize drill and practice rather than teaching thinking or that teach creation science rather than evolution, and these will appeal to many parents. But such problems are pervasive in the current system; a high proportion of elementary teachers think the phases of the moon are caused by the shadow of the earth and that the seasons are caused by changes in the distance of the earth from the sun. The proposal would not solve these problems, but it would make it easier for people like Marva Collins (an African American woman in Chicago who started an academically oriented elementary school) to start schools. I would argue that most parents would want their children to go to specialized schools if they were available.

Another argument against the plan is that rich parents will subsidize their own children's schools by various means, which will undermine the mechanisms for establishing educational equity and for placing less desirable students. If parents want to subsidize the schools, that is all to the good: it will give schools more resources to improve education. Whatever parents contribute is not likely to make education funding more unbalanced than the current system of high per-pupil expenditures in the suburbs and low per-pupil expenditures in the inner cities and rural areas. However, if equality of educational opportunity is in society's interests, as I believe it is, then there is a rationale for offsetting parental subsidies with higher per-pupil expenditures for schools that do not receive such wind falls. In principle, a market mechanism of financial incentives for schools to take less desirable students would automatically act to offset such parental subsidies.

One of the arguments that might be made against such a proposal is that it will produce **a** system like the college system in America, and colleges are not noted for their willingness to innovate. In fact the most tradition-bound colleges, such as Harvard, are the most prestigious, and therefore their practices serve as models for other colleges. This pattern inhibits the introduction of new practices and serves to maintain the didactic approach to education that pervades the traditional colleges.

If we analyze the problem of educational improvement in terms of organization theory[32], we see that it derives in part from the fact that, when consumers choose colleges - as opposed to restaurants or medical treatments - they find if difficult to tell a good product from an inferior one. So in choosing colleges people rely mainly on prestige, and since the most prestigious colleges obtain the best students and the most famous professors, they make a better impression on paper than their educational practices warrant. This effect tends to undermine the drive for self-improvement of any new education plan.

However, I think it can be argued that, in fact, colleges have been much more innovative than the public schools in America and form the strongest part of our education system. Certainly in terms of the infusion of technology and flexibility of curriculum, colleges have been much more innovative. For example, there is more pressure on students in colleges to do their work on computers, and it seems likely that within 10 years every college student in America will have his or her own personal computer. And when new disciplines emerge, such as psychology or computer science, they are much more readily incorporated into college curriculum than into the public school curriculum. The continual birth and death of colleges encourages all colleges to seek their own market niches and to create programs that parents and students will find valuable. It is particularly among less prestigious colleges, which serve the non-elite, that experimentation and improvement through natural selection occur. In public schooling it is with the non-elite that our problems lie, so that, under the proposed plan, innovation is likely to occur where it is most needed.

If a diversity of schools arises and people are given the information necessary to make well-thought-out decisions, then the system will evolve toward better schools. The more effective schools will thrive and multiply; the less effective schools will die out. Existing schools and their personnel will do everything they can to enhance their chances for survival. There might evolve a preponderance of certain types of schools (e.g., essential schools), but that would happen only if they fulfilled the educational goals of a majority of parents and children. However, it is important to recognize that a plan such as the one proposed here will not solve many of the problems of our schools; it will only make it easier for change to occur in a very resistant system.

THE USES OF TECHNOLOGY TO FOSTER EDUCATION REFORM

The arguments in this article have several implications for the course of action that school reformers and technologists should take to make schools compatible with the changing society. In the next century, an educated person will need to be able to learn and think in a computational environment. Most schools do not teach students to use these abilities now, and so a major change ought to be made in the way schools function.

The first implication is that schools should start using computers as tools as much as possible. Many people might object to this step, particularly in light of the ACOT efforts, which to date have had marginal success at best.[33] They would argue that it is better to put resources into developing good educational software, into teacher training, or into hiring computer coordinators, in order to make sure that the technology that goes into the schools is used effectively. The trouble with this argument is that it presupposes that good educational software or teacher training or computer coordinators will lead to more effective use of the technology. In a few cases this is true, but on a broad scale it is not likely to prove so.

I would argue that, if you have computers that are easy to understand and that are powerful tools for doing schoolwork, then people will eventually figure out how to use them. Using computers effectively in schools is difficult because of the various types of resistance described above; thus spending resources to improve usage will not usually work. We should not expect efforts such as ACOT to succeed immediately. But society is making the transition to computers, and the massive educational effort to make the transition is reaching both students and teachers. Herbert Simon refers to this as "education by immersion."[34]

Let me also add that, in the future, the most powerful educational application of computers may not be to use them as tools. Rather, using their capacities for *simulation*, for assistance in *reflection* and self-evaluation, and for *visual displays* may prove to be even more productive. But computers as tools are becoming necessary to do work, and their usefulness to students and teachers will become readily apparent to everyone. The following uses of computers will come into play once computers have established themselves in schools.

Simulation. Computers allow students to carry out tasks they cannot normally carry out in school, from running a business or managing a city to troubleshooting a faulty circuit. The possibility of carrying out tasks that are difficult or impossible to do in school is one of the major educational uses of computers.[35]

Reflection. Another powerful application of computers is for students to compare their own performance to other people's performances on the same task.[36] For example, in teacher education there might be a hypermedia system showing expert and novice teachers teaching some subject matter to students, with critiques on various aspects of the lessons by experts with different points of view and explanations by the teachers of what they were trying to accomplish. Then student teachers could compare videos of their own teaching with other teachers' videos.[37]

Visual Displays. Information that has accumulated over the last century is now contained in vast video libraries. Video is a concrete medium, and people remember visual information more easily than verbal information.[38] Having access to visual materials and explanations may well extend people's ability to learn, particularly in the case of those who have difficulty learning from books and lectures.[39]

In summary, because so many aspects of work are changing to incorporate computers, the nature of schoolwork will make a parallel change. This means that computers will come to be seen as necessary for students and teachers. But other more powerful uses of computers for educational purposes will develop more slowly as computers become commonplace in schools and homes.

All these uses of computers tend to subvert the prevailing, didactic view of education that holds sway in our society. Using computers entails active learning, and this change will eventually foster a shift in society's beliefs in a more constructivist view of education.

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