Kids and Computers: A Positive Vision of the Future

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The period of rapid growth and great enthusiasm that heralded the introduction of computers in school has passed. Those of us involved in this enterprise are pausing to consider the achievements of the last decade and the changes that the next decade is likely to bring. And well we might.

The way in which the Laboratory of Comparative Human Cognition (LCHC) has interpreted the accumulated evidence concerning the consequences of computerization of basic education is that, by and large, the net effect of the microcomputer "revolution" in primary education has been to reinforce and exacerbate previously existing inequalities of educational achievement. Instead of realizing a long-standing dream of general increases in basic literacy as a result of children's involvement with microprocessors in their classrooms, we seem to be witnessing a case where the rich are getting richer and the gap between them and the poor is widening (Cole, Griffin, & LCHC, 1987).

Hence, consistent with our long-term concern about the roles schools play in creating social inequality and our current involvement in exploring the potential of computer-mediated educational activity for promoting learning and development, we will focus our comments on ways to counter what we perceive as the pernicious side effects of the current drive for computerization of the schools.

The Current Situation

As summarized in our recent monograph on programs that increase the involvement of women and minorities in mathematics, science, and technology (Cole, Griffin, & LCHC, 1987), the manner in which computers are being employed in America's classrooms has caused the level and involvement with technology for women and minorities to decrease relative to Anglo/male norms. For example, a national survey of 1,082 schools using microcomputers revealed the following:

1. more computers are being placed in the hands of middle- and upper-class children than poor;
2. when computers are placed in schools for poor children they are used for rote drill and practice instead of the cognitive enrichment that they provide for middle-and upper-class students;
3. female students have less involvement than male students with computers in schools, irrespective of class or ethnicity (Center for Social Organization of Schools, 1983–84; reported also in Cole, Griffin, & LCHC, 1987).

The first of these findings is completely unsurprising, and it seems safe to assume that the situation is even more serious than it appears, since affluent communities are likely not only to have more computers, but more powerful ones in school and heavier involvement with computers at home. After all, one of the fundamental advantages of affluence is the opportunity to "provide the very best" for one's children.

The second finding is far more disturbing, for it suggests that even in the unlikely event of changes in local, state, and federal policies to insure equal educational opportunities for America's growing underclasses, mere access to equal equipment will be sadly insufficient. What seems to be occurring is that long-standing beliefs about the mental characteristics of the populations involved and educational strategies developed to fit those beliefs are being carried over from the paper-and-pencil classroom into the computerized classroom. In particular, the rote drill and practice applications of computers that predominate in poor communities represent the confluence of a psycho-educational ideology that makes the following assumptions:

1. Education is a "bottom-up" process. Children must first master the basics before proceeding to higher-order problems. They must learn letter-sound correspondences before reading words, words before sentences, sentences before paragraphs and stories. They must learn to add and subtract before they can learn about lengths and areas or before they can do word problems (Durkin, 1979, 1981; LaBerge & Samuels, 1974; Perfetti & Lesgold, 1979).

2. Ethnic minorities and the poor lack the basics, so they should be trained in them until they reach automaticity. Whether or not it is linked with Arthur Jensen's theory of genetic determinism, this latter view coincides with his view that there is a lower, "Level 1" kind of learning/thinking that precedes higher, "Level 2" learning/thinking both ontogenetically and in the mastery of school subjects (Barr, 1975; Jensen, 1972).

It is our belief that this "bottom-up," "level 1/level 2" theory of learning and instruction is wrong in principle and pernicious in practice. In principle, such skills as mature reading and mathematical thinking require *both* top down (level 2) *and* bottom-up (level 1) processes (McClelland & Rumelhart, 1981; Frederiksen & Warren, 1987; Resnick & Omanson, 1987). This basic understanding is sufficiently well established for Richard Anderson to proclaim the "law of meaningful processing" (Anderson, Mason, & Shirey, 1983). As applied to cognitive development in general (Donaldson, 1978; Ghatala, 1986; Vygotsky, 1978), modern cognitive studies of reading and mathematical thinking urge the creation of instructional contexts rich in "human sense" that can serve as the intellectual-motivational medium within which development of more complex psychological functions are promoted.

In practice, as described by Moll and Diaz (1987), teachers who adopt a bottom-up, decoding to comprehension, Level 1 approach to the curriculum on the basis of Level 1–Level 2 educational theories underestimate the intellectual resources that their children bring to the instructional setting and unwittingly create teaching-learning interactions that are unsuited to the children's pedagogical needs. When they fail, remediation is "more of the same," worsening an already unfortunate situation.

We adhere, instead, to the principle that "development only occurs within the constraints of the whole" (Hamburger, 1957), or its modern cognitive science substitute that learning can occur only through the interaction of both "bottom-up" and "top-down" processing. We strongly advocate instructional strategies (with or without involvement of computers) which embed practice on elements of complex activity like reading or mathematics in meaningful contexts where the constraints of the fully developed (whole) system can continuously promote their fusion in developmentally productive ways (Griffin & Cole, 1987). In our opinion, computer-mediated education, properly conceived, offers marvelous tools for overcoming the false Level 1/Level 2 dichotomy, despite the unfortunate tendency of modern practice.

A similar strategy applies to explaining and seeking to overcome the third finding, the relative absence of females from the "computer revolution" in the schools. Here cultural stereotypes about females' "natural" uninterest in scientific activity, dubious claims about the neurological bases of such differences, and the way educational topics are implemented on computers combine to reproduce routinely a separation of the sexes. This separation works directly against the goal of bringing all of our citizens into a new culture of literacy that incorporates modern technology.

Scholars who do not accept the apparently commonsensical explanation that girls are "naturally" less interested in computers and related activities than boys have begun to delineate the sociocultural reasons for such preferences. In a variety of ways, both the context and the manner in which computers are introduced into educational settings tend to be discouraging to the participation of girls, and the pattern of discouragement is self-reinforcing over time. For example, a failure to take advantage of the diverse uses to which computers can be put has an immediate impact on differences in participation by sex. Thus, when computers are introduced in the context of straight computer-programming courses, boys demonstrate a higher level of interest and achievement (Hawkins, 1985; Hawkins, Sheingold, Gearheart, & Berger, 1982; Pea, Hawkins, Clement, & Mawby, 1984). In contrast, when computers are introduced as tools for writing and word-processing, boys and girls are equally involved (Kurland & Pea, 1983; Whooley, 1986).

A number of studies and pilot projects show that sex differentials in computer literacy can be overcome if these factors are seriously addressed. When the software and the learning context are designed with a sensitivity to the concerns and reactions of girls as well as boys, girls readily become involved with computers. Some recent studies of the use of computers in math and science education conclude that two features seem to be particularly helpful (Hawkins, 1985; Hawkins & Sheingold, 1986; Linn, 1985). First, girls tended to enjoy the opportunity for collaborative and cooperative learning experiences, rather than purely isolated and competitive ones. Second, they became enthusiastically involved when the computer was presented as a flexible tool for solving concrete problems of immediate interest to them, and this served as a point of entry for them into increasingly abstract scientific language. Significantly, these two features of cooperative and activity-centered learning have been central to those educational programs, such as the EQUALS program at Berkeley's Lawrence Hall of Science, that have been most successful in introducing girls to math and science, even without computers (American Association for the Advancement of Science, 1984). Thus, the "male" aura of math and science education, which presently acts as one obstacle to girls' attainment of computer literacy, does not have to be accepted as given. Rather, the innovative use of computers can contribute to overcoming this barrier as well. The challenge is to apply the successful lessons of the past and transform them appropriately to take advantage of the potential of this new medium.

An Achievable Goal: Back to the Future

The current national alarm at the deteriorating state of American education (Applebee, Langer, & Mullis, 1988; Mullis & Jenkins, 1988) sets the agenda for the future of computer use in the schools. Whatever measures are adopted, they should significantly raise the basic level of literacy, including, but not restricted to, the "technological literacy" of our population. This is a gigantic task—given the current low achievement levels, the need for increased teacher preparation, and the changing character of the workforce—which challenges the content of the existing curricula (Miller, 1988; Mullis & Jenkins, 1988; Noyelle, 1985). What is called for is a far-reaching set of transformations in many areas of our society, a task that goes far beyond the purview of this paper.

As a practical beginning, we propose a relatively modest goal which requires returning to the activity-based educational reforms of the 1960s and implementing them comprehensively in our nation's schools. The important difference is that today these programs can be supplemented in crucial ways by the support and benefits of computer technology (broadly understood to include computer-based communication). This factor would enable activity-based programs to permeate the entire curriculum, not just the sciences stressed in the 1960s.

These and similar educational reform projects that are part of the approach we propose can be found summarized in our recent monograph on programs that increase involvement of women and minorities in mathematics, science, and technology (Cole, Griffin, & LCHC, 1987). There we found that recent studies of classroom organizations that resulted in positive changes in the quality of learning emphasize the same characteristics that were common in the most innovative curricula during the 1960s (for example, Glass & Smith, 1987; Sharan, Kussell, Hertz-Lazarowitz, Berjarno, Ravis, & Sharan, 1984; Skon, Johnson, & Johnson, 1981; Slavin, 1978; Stodolsky, 1984). Since those programs were successful in involving under-represented segments of our society, and since they were rather large-scale in both character and scope, it will be most advantageous to review the characteristics of those programs in some detail.

A number of programs can serve as a model for starting such a reimplementation process. Among them would be the Elementary Science Study Curriculum developed by the Education Development Center (EDC) in Cambridge, Massachusetts, and the Science Curriculum Improvement Study from the Lawrence Hall of Science in Berkeley, California.

These and similar educational reform projects of the 1960s advocated breaking large classrooms with teacher-led presentations into lessons for small, cooperative working groups. (For more detailed discussions of the small group strategy see for example, Cole, Griffin, & LCHC, 1987; American Association for the Advancement of Science, 1984; Holdzkom & Lutz, 1984.) These studies mainly involved peer groups; they were, however, composed of children with heterogeneous levels of achievement. Initial structuring of the hands-on activity, plus the choice of the materials, was critical to ensure that the students, through discussion and experimentation, would come to discover the principles and problems of the phenomena under investigation. Thus, the groups were presented with goal-directed activities and a good deal of hands-on work, and they were asked constantly to shift between theoretical and practical activity. The role of the teacher, or the other expert-adult, was not simply to instruct, but rather to direct and facilitate the discovery of the solution. The curricula emphasized applications of science and math, which were further incorporated into other subject areas. In addition, the emphasis of the programs was on enrichment rather than remediation, the teachers expecting—and the students experiencing—high levels of successful performance.

An important characterisitic of the 1960s reforms that fits well with the activity-centered small group approach is that they involved practicing scientists and researchers. The researchers attempted to make explicit the principles that teachers might use for implementation. Thus, they attempted to provide teachers with a wide range of "do-it-yourself" hints using readily available materials. Furthermore, they represented a mechanism for continuing teacher education, including interaction with practicing scientists whose expertise and role modeling could become part of classroom life.

Overall, evaluations of the 1960s activity-centered programs seem very positive. As Kyle (1984) states in his meta-analysis of the relevant studies:

> Evidence shows that students in such courses had enhanced attitudes toward science and scientists; enhanced higher-level intellectual skills such as critical thinking, analytical thinking, problem solving, creativity, and process skills; as well as, a better understanding of scientific concepts. Inquiry-oriented science courses also enhanced student performance in language arts, mathematics, social studies skills, and communication skills." (p. 21)

One would imagine that such reported success would have led to the wholesale adoption of such methods in our schools, a course of action which, if implemented in the 1970s, might have prevented the not-so-gentle slide of our children's academic achievements. Despite their initial success, there has been little adoption of these curricula; they are found in fewer than 10 percent of today's classrooms (Kyle, 1984). As experiments, they were not implemented through the normal channels of curriculum change and, therefore, did not penetrate deeply into the institutional structure of schools. Thus, we are faced with a conundrum: small-group, student-involved or -led, hands-on educational activity is successful, yet educators seem to ignore the evidence (Holdzkom & Lutz, 1984).

Our analysis is that the educational reforms of the 1960s never became institutionalized because, to put the matter bluntly, they were too expensive to maintain. During the reform effort, highly motivated and enthusiastic teachers received material support and encouragement from their local school systems and local communities, often in the form of participation by outside practitioners. Once the reform movement gained momentum and support among teachers and classrooms, no changes were made on the organization of schools which could have institutionalized these reforms. As a result, when the federal funding which supported these programs was removed, the teachers could not in themselves sustain their level of effort, and also successfully transmit the required skills to a significant number of other teachers.

Given the potentials of the computerization of education today, it seems a worthy proximal goal to reexamine and reimplement with better support the "successful" curriculum interventions of the 1960s. Moreover, we argue that the effort to implement those curricula using modern information processing and communications technologies has the potential to advance the far broader agenda of creating a new and more equitable culture of literacy, a goal which was certainly not fully achieved by the curriculum reforms of the 1960s.

Computers as Media of Activity-Centered Instruction

The question of how computers can help to support and realize activity-centered, hands-on curricula has two major facets, each requiring development of different potentials in computer technology. The first focuses on the organization of educational activity within the classroom; the second focuses on links between classroom-level activity and the broader context of which the classroom is a part. Although these two facets are two sides of the same coin, we will discuss them separately for the sake of clarity.

The Organization of Within-Class Activity Systems

When we look at the kinds of within-classroom organization that constitute successful use of computer technology, we find that central to successful computer-mediated education is a special quality of the relationship between children and the teacher, just as it was in the activity-based curricula of the 1960s. For example, a study by Shavelson, Winkler, Stasz, Feibel, Robyn, Shaha (1984) found four patterns of computer use in the classroom, only one of which, called "orchestration," provided a significant improvement in the academic achievement of children through the use of microcomputers. In those cases, the "successful" teachers used several types of software which they integrated into the curriculum, coordinated the microcomputer activities with other instructional means, and stressed both cognitive and basic-skills goals. "Orchestrator" also applies well to the kinds of teaching activity needed to organize classrooms into small groups, classrooms in which the teacher, teachers' aides, and perhaps older "peer teachers" move from group to group, joining in with the children to facilitate and direct the interactions among the groups (Levin, Riel, Boruta, & Rowe, 1985; Levin, Riel, Miyake, & Cohen, 1987; Newman, 1985; Riel, 1986).

An important potential of the introduction of computers into classroom activity is that it can support the teacher to organize collaborations and goal-oriented work among the students. This can be accomplished because computers allow and foster interactions in which the children work together instead of separately. In our own work, and the work of several others (for example, Levin, Riel, and their colleagues; Newman; and Hawkins), this cooperative work is encouraged by computer sharing. Children who work together at a computer are routinely observed to correct each other's mistakes, cooperate in the completion of assigned tasks, and discuss the assignments in ways that clarify the task, even when neither partner appears to understand it at the outset. Some specialization within tasks has also been observed. For example, one student in a pair handled typing and spelling, while the partner concentrated on more global issues such as the construction of the essay and sentence coherence. Growing evidence suggests that collaboration at a machine reduces low-level errors and creates support for higher level activities (Laboratory of Comparative Human Cognition, 1982; Levin & Souviney, 1983). Two students are likely to have different skills. By working together and dividing the labor of the task, they can unite their separate strengths to accomplish the task. In the study by Mehan, Riel, and Moll (1985), students began by taking short turns at the computer. Gradually, the size of the turn units changed: Students started out dividing the labor at the level of keystrokes; as they developed some proficiency and gained control over the coordinated parts, they began to write one story per turn, providing for a kind of role-alternation between writer and assistant.

Another element which contributes to the construction of exemplary programs using computers in classrooms is the rich interactions afforded by interactive microworlds, accessible languages that allow modeling of empirical phenomena, user-friendly word processors, local area networks, and so on (Newman & Goldman, 1987). Simultaneously, these new forms of activity support the necessary change in the teachers' role from becoming less the providers of content-specific information and more the facilitators of students' acquisition of knowledge. Instruction shifts from emphasis on information-giving to emphasis on helping students to find the relevant information, learn how to solve problems, ask questions, think critically, and communicate ideas (Collins, Brown, & Newman, 1987; Diaz, 1988; Hawkins & Sheingold, 1986; Shavelson et al., 1984).

We should not, however, stop short at the walls of the classroom. We believe that development arises from a positive feedback between within-context (the classroom) and between-context (the classroom and all other contexts in which it partakes) interactions (Cole, Griffin, & LCHC, 1987; Laboratory of Comparative Human Cognition, 1983). Hence, we need next to turn to the between-context interactions which new information technologies can support.

Supporting Inter-Context Interactions

The curriculum reforms of the 1960s provided important opportunities for both students and teachers to draw upon resources outside the classroom. For instance, schools entered into partnerships with museums, which children visited regularly, and where they sought assistance in their projects. Teachers were able to confer with each other and with practitioners who worked in their fields of instruction. These interactions supported their efforts to engage their students. Skilled practitioners also advised teachers on how to proceed when the children's explorations took them beyond their level of expertise.

When supplementary funds for activity-centered curricula dried up in the early 1970s, the links between classrooms and resources outside of the school were particularly hard hit. Children no longer had access to the intriguing information and possibilities for role modeling provided by interactions with practicing scientists. Teachers lost not only the stimulation of these same practitioners but peer support as well, because the time needed to maintain contact with other teachers became an extracurricular demand with no hope of extra compensation.

Modern computer technology, when used as a component in a telecommunications system, offers a link between children, teachers, and the outside world in educationally powerful ways. Existing evidence cited below shows that when classrooms are linked through computer networks to each other and to institutions outside the school, teacher and student activity can change qualitatively, in precisely the way envisioned in the curricular reforms of the 1960s.

Studies of the use of telecommunications as an integral part of overall educational activity consistently find that, when properly organized, telecommunications provide rich opportunities for children to articulate new goals. It enables them to reflect on their own learning, to use writing as a tool of both communication and thought, and to create social contexts that are not merely "passive backgrounds" for learning but arenas for goal-oriented, reflective problem-solving (Diaz, 1988; Levin et al., 1985; Newman, Brienne, Goldman, Jackson, & Magzamen, 1988).

Potential Benefits for Children

A crucial step in creating the proper organization of telecommunications-mediated instruction is to get beyond the assumption that telecommunications access to other people and contexts (classroom, databases, and so on) is sufficient to make a positive difference in the quality of classroom instruction. It is not (Cole, Griffin, & LCHC, 1987; Riel, 1986). Rather, just as within-classroom, small-group activities have proven powerful when they encourage *both* collaboration among students *and* a new role for the teachers, so telecommunications becomes a medium for productive educational activity only when it facilitates joint activity at a distance. In order to do so it must support the role of teacher-as-orchestrator and provide rich opportunities for children to communicate in detail about jointly addressed problems.

A variety of projects have effectively organized joint activity at a distance that naturally motivates writing and reflective thinking about one's non-problem-solving activities. In an early project of this kind begun by Jim Levin, Margaret Riel, and their associates at the University of California, San Diego, researchers and teachers collaborated to support the joint production of a newspaper dubbed "The Computer Chronicles" by children in Alaska and those in suburban San Diego County. As reported in a number of publications (Levin et al., 1985; Riel, 1985), the initial stages were typically discouraging. Children found writing articles for the (dimly understood) "newspaper" difficult and generally uninspiring. Their orientation began to change, however, when they had to meet as an editorial board to consider entries from their distant partners. Often these entries were extremely intriguing—children living in Alaska loved reading about surfing, while those in

California were fascinated with seal hunting. Although intriguing, these first efforts were usually too skimpy to prove satisfying, which forced the children to suggest improvements and to become critically aware of their own writing processes. Riel (1985) reports that members of the editorial board soon began to request time on the computer during recess to edit their own contributions to the paper. These children also displayed gratifying improvements in the quality of their written products as well as greatly improved attitudes toward writing.

Generalizing the Alaskan–San Diego experience, this group of researchers and teachers formed an Intercultural Network which concentrated on methods for promoting the kinds of joint activity that render computer networking a useful adjunct to normal classroom computer use. Retaining the joint newspaper-writing activity as an organizing device, the researchers have constructed projects around such topics as cultural celebrations, comparative analysis of lead news stories in local papers, observations of Halley's comet, water conservation, and local social problems of intense interest to the students (for example, the problem of bullying and suicide in Japanese schools, which was raised by a Japanese participant) (Riel, 1986).

At first glance it might seem that networking which involves communication in more than one language would be a detriment to the construction of joint activity, except where language learning was the specific object of study. Experience has proven otherwise. In an early experiment on the organization of joint computer-mediated activity using telecommunications in San Diego, Diaz (1988) found that students of Hispanic origin became excited and involved when they encountered material coming over the network in Spanish as well as English. These occasions provided a rare circumstance in which knowledge of Spanish was treated as a social advantage instead of a stigma, a finding also reported by Riel (1986). Diaz reports that the students' language arts skills increased in both Spanish *and* English.

A crucial resource which computer-mediated communication provides for organizers of joint activity at a distance is that it occurs in non-real time (Black, Levin, Mehan, & Quinn, 1983; Scollon, 1983). The fact that a normal answer is not expected for twenty-four hours or more means that recipients of messages can work on them "off-line," looking up information they are lacking, consulting with more expert speakers of a foreign language, getting a partner or teacher's reaction to a proposed answer, and so on. This reduced time pressure not only removes problems of translation but converts them into useful learning experiences.

Potential Benefits for Teachers

Thus far we have concentrated on ways that joint activity through telecommunications provides resources for the organization of children's activities. Every bit as important is the way such links support teachers' work in organizing the children's activity by providing teachers with opportunities to discuss teaching strategies with other teachers, to obtain specific suggestions for how to implement particular curricular objects, and generally to overcome the isolation that many teachers report (Katz, McSwiney, & Stroud, 1987; Newman, 1986; Riel, 1988).

Katz and her colleagues, for example, created a network for high school science teachers in New England, using a conferencing system, *Common Ground*, specially designed for this purpose. While there were difficulties involving some teachers, researchers reported that in the first year of operation, about 25 percent of the participating teachers logged onto the system once a week or more, and that only 10 percent said that the network had not served their interests (Katz et al., 1987).

Two themes dominated the positive evaluations: the opportunity to interact with colleagues and the opportunity to obtain specific information. Not surprisingly, these benefits appeared greatest to those teachers who were most isolated, either because they were in a small school ("I am the only chemistry teacher in my school") or because they were teaching advanced courses and could obtain little collegial support because of their level of expertise.

A common characteristic of both the teacher-oriented and student-oriented uses of telecommunications discussed thus far is their relatively small scale; typically, a few classrooms in different geographical locales have been teamed up for purposes of joint interaction. In the Katz et al. study, most teachers were working in or near the Boston area, and the group of participants numbered approximately forty.

It makes perfect sense to work out model systems for the incorporation of telecommunications into educational practice on a manageably small scale, but, assuming that such activities have significant potential for making a real difference in education, a crucial task is to discover what it will take to implement them on a mass scale. The existing research on this topic is very thin, but the problem is being actively addressed in a number of large-scale projects.

Riel (1988) summarizes the strategies employed by four such projects, each of which appears to concentrate on providing direct support for teachers with some participation by students. The mode of participation differs from one project to the next in ways that ought eventually to provide a better idea of the potentials and pitfalls of mixing telecommunicated and face-to-face education and teacher support. For example, the AT&T Long Distance Learning Network, which includes 275 users in 7 countries, is organized into "Learning Circles" that focus on such topic areas as geography, social sciences, writing, ecology, and biology. Communication in the learning circles is directed either from the moderator to the group, or from any member to the group. By contrast, the Free Educational Mail Service (FrEdMail) project is organized into two major conference groups (IDEAS for teacher exchange and KIDWIRE for teachers and sometimes children to post student work). The FrEdMail project allows one-to-one as well as one-to-many communication. The McGraw-Hill Information Exchange and the National Geographic Kids Network (Kidnet) offer interesting variations on the AT&T and FrEdMail efforts, mixing clusters of teachers and children in different ways. For example, Kidnet, which began as an effort to develop new science curricula and to foster active problem solving, adopted the strategy of having children (under their teacher's guidance) gather potentially useful scientific information which they contributed to a national database on acid rain. The project fosters communication among teachers and students and practicing scientists.

Each of these projects provides a mechanism for overcoming the anonymity and unresponsiveness of mass systems by making smaller clusters the de facto units within which most of the interactions take place. The AT&T project constructs "learning circles" of four to eight classrooms, FrEdMail has given rise to many small projects with two to ten groups participating, McGraw-Hill has engendered sixty to seventy conferences on specific topics in which fifteen to twenty-five teachers participate, and Kidnet has created clusters of ten to twenty classrooms each to discuss issues posed in working on problems common to the network as a whole.

There appears to be both good news and bad news in these (relatively) large-scale studies. The good news is that such systems are easily, and perhaps naturally, broken down into smaller subsystems which can be combined for special purposes, thus maintaining the benefits of large-scale technology without losing the benefits of a smaller, more human scale. The bad news is that so far there is no evidence that such large-scale systems can be mounted affordably. Large scale means large geographic distribution, which in turn means use of private communications facilities, including the telephone and satellite-based conferencing utilities. It remains to be seen whether such systems can simultaneously be widely accessible and affordable, yet remain profitable.

Additional Elements in the Vision

Thus far we have restricted our attention to the reorganization of classroom activities and teacher support systems that modern computer and telecommunication technologies make possible. It would be shortsighted, however, to ignore the fact that educational activities are not restricted to school or homework. Our research group, among others, is currently exploring the potential of introducing computers and telecommunications activities into existing institutions, such as libraries and youth clubs, which have far greater freedom than schools to experiment with innovative educational activities. Such activities can be useful not only in their own right; they can provide models for activity-centered curricula that schools can subsequently adopt (Cole, 1987).

Nor should we lose sight of the fact that "old" new communications technologies such as television continue to offer untapped resources for within-school education and for linking school and home, both through TV programs (such as Bank Street's "Voyage of the Mimi") and various "homework hotline" projects, which keep children involved in their education outside of school hours. Widespread access to computer bulletin boards and conferencing systems can only reinforce the generally underutilized potential of such systems.

A Utopian Vision

It is impossible to view the current educational problems of the United States without coming to the conclusion that what the situation demands is a "cultural revolution" involving broad masses of our population in basic literacy activities. Such a revolution would provide a broad and solid foundation for the kinds of specialization that the future will demand. At the same time, it is clearly impossible to accomplish such a massive change simply by pouring money into the schools to reduce classroom sizes or by raising salaries to make the demands of teaching attractive to talented young people, or any of the other "war on ignorance" plans that are presently under consideration.

We began this discussion with a modest "first step" proposal: use new computer technologies to implement on a broad scale the successful educational reforms of the 1960s. We believe that to be a useful agenda, but unless it sparks a chain reaction that ignites reform in all parts of the curriculum and the community, it will not bring about the required changes.

Assuming for the moment that our recommendations for the recontextualization of educational activities within and between classrooms and communities contexts were adopted, we think they would fail without a self-conscious and highly organized effort to keep the costs of computerization very low. Unfortunately, this is not the trend we see. Instead, strong ideological and commercial forces (if we can be allowed to separate the two for purposes of discussion) are putting pressure on the schools to buy more and more powerful machines that can implement more and more powerful interactive microworlds and intelligent tutoring systems. As understandable as the desire for powerful, stand-alone, computer-based educational activity systems may be, the thrust of current efforts takes teaching out of the hands of teachers, thus representing a new attempt at creating the "teacher-proof curriculum." Broad involvement of our children with computers will be best served if computerization is controlled by, and in the service of, teachers. Moreover, we advocate the use of inexpensive machines that are widely available. Rapidly disappearing computers of the Apple 2E variety satisfy these goals. Such machines ought to have modems routinely built into them to support easy access to telecommunications.

This vision takes its inspiration from the early days of radio, when kits were readily available in any department store, along with spare parts and suggestions for how to build bigger and more complex systems as the user desired. Applied to the modern scene, this vision implies that school-standard computer components should be available in hardware and variety stores throughout the country, with a ready supply of spare parts. The most expensive elements in the system (disc drives, for example) would need to be specially subsidized.

Just as important would be inexpensive access to telecommunications utilities. In an era when the very people who are seeking to promote teleconferencing for educational purposes are also raising telephone rates beyond the reach of the poor (Sweet & Hexter, 1987), we need some means for children to obtain access (perhaps through a combination of specially subsidized 800 numbers and free time on NASA-launched satellites), so that we can break the current cycle of the rich getting richer and the poor being left further behind.

Such a vision in no way precludes continued work to develop high-powered educational activities using the cutting edge of computer technologies, but it does put the emphasis where we think it is desperately needed—on broadening the base of literacy instead of trying to raise the pyramid of knowledge by pulling upward from its apex.

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