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ABSTRACT

Without a deliberate emphasis on designing and using technology to improve the organization of schooling, even the best learning technologies will have limited long-term impact on our educational system. Research has identified two key conditions of good schooling: students can learn well when they are actively engaged with multiple resources and people, and they can learn well in environments where they are personally well known. Technology can be the key to realizing these conditions. The most powerful way to integrate technologies into the schools is in concert with organizational change. Planning for reform must deliberately consider the contributions of technology to reorganizing schools. Examples drawn from the Dalton School (New York City), the Charlotte Middle School in Rochester (New York), and the Brooklyn Technical High School (New York City) illustrate the effective use of technology in schools to broaden resources open to both teachers and students. Reorganizing schools for thoughtfulness is neither short term nor simple. The process is enhanced by using technology as a resource for school reorganization. (Contains 22 references.) (SLD)

CENTER FOR TECHNOLOGY IN EDUCATION

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TECHNOLOGY AND THE ORGANIZATION OF SCHOOLING

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Discussions of the promise of technology for improving education have focused too narrowly on *isolated learning* with machines. While the careful design of computational, visual, and communications technologies for thorough and thoughtful learning is essential, a decade of research has tempered the view that hardware and software alone are sufficient. Without a deliberate emphasis on designing and using technology to improve the *organization of schooling*, even the best learning technologies will have limited long-term impact on our educational system. Why?

Accumulated evidence presents a consistent picture of the conditions needed for effective learning (Berryman & Bailey, 1992; New York State Curriculum and Assessment Council, 1992; Resnick, 1987). It is not a picture that is congruent with schools' traditional view of learning—that students learn best in isolated, even if attentive and intensive, bite-sized encounters and exercises with subject matter. The traditional view has led to school organization that provides well for rote learning and relatively passive absorption of information. In contrast, current research argues that students need to be immersed in conditions that teach and encourage them to be thoughtful most of the time. Schools must be organized to supply students with excellent materials and tools, but also to promote inquiry, interpretation, discussion and argument, judgment, and revision of ideas and products. Two key conditions for good schooling can be extracted:

- Students learn well when they are engaged in active exploration, interpretation, and construction of ideas and products with multiple resources and people throughout the disciplines. This is not simply a separate course in problem solving, but must be basic to the structure of work throughout students' years in school. The requirement of sustained and active engagement has implications for the activities that form the hub of school experience—tipping the balance from direct passive instruction toward project-based collaborative work combined with seminar discussions. Collins (in press) points out that in the design of schooling there is a tension between *memorization* and *thoughtfulness*. Gaining automaticity in a skill can free the mind for thoughtfulness, like memorizing multiplication tables. But isolated, automated skills, it turns out, are not the sequential building blocks that lead to skilled problem solving and flexible complex thinking (Means, Schlager, & Knapp, 1990). Sustained work on meaningful tasks is a condition for becoming thoughtful, and indeed, automaticity may best be learned by practice in contexts that reflect the use of skills in the world. There is some indication that this kind of engaged work and interaction has actually *decreased* in schools over the last decade (Darling-Hammond, 1990).
- Students learn well in the environments where they are personally well known. The best instruction offers individualized diagnosis and help; students bring very different conceptions and misconceptions to their encounters with any body of knowledge, and they bring different personal qualities and

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problems. This has implications for the size and schedule of schools and for the ways relationships are structured among students and faculty. There is evidence that schools should have 500 or fewer students, and teachers should interact with no more than 40 to 50 stu–dents whose work they can know well (it is not uncommon now in many high schools for a teacher to work with more than 150 students in a single day; some universities' undergraduates may never experience a class of less than 50 in their first years) (Sizer, 1984).

Technology and Learning Conditions

Technologies can be key to realizing these conditions of effective schooling. In fact, it is unlikely that schooling *can* be reorganized without broad and careful planning to use current and emerging technologies well. But to use them to advantage requires challenging many assumptions about an effective educational process. Many of these assumptions concern not simply curriculum, but the nature of the organization where students and teachers work together. The kind of rethinking required is seldom comfortable. Educators and, more important, parents are being asked to change their minds in some very significant ways about how schools work.

Reorganization to feature significant tasks where each student is well known presses on the way time, space, and relationships have long been structured in schools. More flexible scheduling is required (for meaningful project work, for group work, for reflection and revision, for thoughtful assessment of learning, for curriculum planning and modification). Differently organized space promoting private and group work, and access to resources press on traditional architectural decisions about large group spaces. The relationships among staff, administrators, and students shift considerably when students are asked to take increasing responsibility for accomplishing whole and complex tasks.

Thus, the most powerful way to integrate technologies into schools is in concert with organizational change, not as independent learning systems or isolated rooms that remove students from the personal interactions central to schooling. This means incorporating technologies as a key resource to these changes rather than, as is common now, viewing technology as a separate, difficult, and expensive problem.

- Because technology *can* support significantly enhanced learning conditions does not mean that it *will*. The experience of the last decade provides abundant evidence that technology does not of itself radically alter the conditions of schooling. Computational hardware has found its way into schools, but there is still far from enough; and it is the rare school that is up to date. In many schools, computers remain segregated in laboratories, which students visit weekly for 45 minutes of "hands-on" experience with the keyboard. Commonly, when integrated into instruction, technologies are absorbed into the way schools have traditionally done business. For example, integrated learning systems (ILS) have been purchased by a large number of schools. ILS tend to be designed around a delivery-of-information model of education. Comprehensive hardware and software packages—which can vary widely in quality—are designed to cover concepts and skills in largely traditional ways. The software generally provides repeated, sequential practice of subcomponent skills. When well designed, the structured practice can be motivating and quite effective for limited instructional goals; it is weighted toward the automaticity side of the instructional balance. ILS tend to absorb easily into traditional schooling without fundamental challenge to its organization.

Research has also shown that technologies designed to promote thoughtfulness can likewise be assimilated to the way things are traditionally done. The goals of these kinds of technology-based materials focus not simply on learning facts and procedures, but on helping students to grasp and practice the kinds of inquiry, interpretation, and judgment that are key to expertise within a discipline. Cognitive studies demonstrate that such materials *can* qualitatively alter learning in many disciplines—from geometry or calculus, to dynamics or archeology, to romantic literature or the classics. But school-based studies repeatedly reveal that even these materials can be readily converted to traditional passive lecture-based instruction (Martin, 1987). [illegible] hardware and software are always interpreted in practice. To use the technology well, the organization of the learning environment must be criticized.

Planning for reform must deliberately consider the contributions of technology to reorganizing schools.

We briefly consider below five areas where technology has been shown to have an impact. The impact is, of course, not limited to these five, but they are prominent in the last decade's research: (l) activities organized around student-centered learning; (2) collaboration in work; (3) changing teachers' roles in classrooms; (4) professional interaction among educators; and (5) how students' knowledge is assessed. The areas are illustrated through school example, where appropriate.

When technology is thoroughly designed into curriculums for student-centered learning, it functions quite differently than in isolated computer-based learning. For example, the *Archeotype* project at the Dalton School in New York involves sixth grade students in a simulated archeological dig in ancient Greece (McClintock, 1992). Groups of students "dig" in each of four quadrants of a Macintosh-based simulation of a classical site. They use computer-based tools to measure and classify the artifacts they uncover (e.g., a vase or dagger). They must consult a variety of sources to interpret the artifacts, including the Perseus database,[1] books and other materials in the library, teachers, and visits to museums. Students' research is stored in a common database. When they have completed the exploration and interpretation of the finds in their quadrants, the groups of students must pool their research to come up with an overall interpretation of the site—there are no right answers. Students produce reports about their investigations, some of which are hypermedia-based. The experience is designed to emphasize historical interpretation skills: construction, development, and use of evidence in argumentation. The facts about classical culture are better learned when embedded in tasks that require reasoning about specific finds and comprehensive judgments about the site. Research on students' learning in this environment has demonstrated that they, in fact, learn a great deal about these historical inquiry skills from this technology-infused curriculum, as well as specific information about ancient Greece (Tally & Honey, 1992).

Students at the Charlotte Middle School in Rochester, NY, have been engaged in a technology-enhanced project-based curriculum for the last three years.[2] Charlotte is a public school with a majority of students who face the challenges of the urban poor. The curriculum was designed to help the school move from the traditional organization of separate disciplines taught in isolated 50-minute periods to a "house" structure in which groups of students work consistently with an interdisciplinary team of teachers. The curriculum was based on cognitive apprenticeship theory, which embeds control and heuristic strategies for learning and communicating information into sustained tasks that are meaningful to students.

In the first year, the *Discover Rochester* curriculum enabled students to conduct research about significant scientific, mathematical, historical, and cultural topics in their community. Small groups of students investigated separate topics and then combined their work into an interactive hypermedia exhibit that was displayed at the Rochester Museum and Science Center. At the core of the project was a set of technology-based tools that allowed students to conduct, record, and communicate their work. The students selected to participate in the first year of the project were those considered least likely to succeed in school. The curriculum was structured to help them acquire research, technology, and collaborative skills—skills that had eluded them in the traditionally structured school. Results indicate that the design has had a powerful effect on the organization of the school. It has grown from a one-day-per-week commitment for one group of students, to a five-day curriculum for all. Research about student learning also indicates that students are learning more, and gaining mastery over more complex skills, than was possible in the past.

The Dalton and Rochester experiments—focusing on very different populations of students—were each carefully designed to embed the technology in a complex and long-term activity structure featuring group inquiry and problem solving. All parts of these curricula were coordinated to create a learning environment: software selection and design; nature of additional resources; activity structure; composition of group work; teachers' roles; assessment. A number of studies have suggested that the appropriate use of technology resources can significantly reduce the "lockstep" quality that characterizes much of classroom learning—unyoking students from each other

[1] Perseus is available from Yale University Press. It was developed at MIT with funding from Annenberg/CPB.

[2] Contact Dr. Sharon Carver. Graduate School of Education, the University of Rochester, Rochester, NY 14627.

so they are not required to move at the same rate through identical material. Designs that increase the motivated engagement of students in thinking appear to be characterized by reduced lockstep in classroom activity, and a deeper connection of students with the materials and each other over an extended project period. In these experiments, the technology was "tucked into" the organization of schooling to facilitate the learning of skills and concepts as part of extended projects.

From the beginning of the introduction of microcomputers into schools in significant numbers in the early 1980s, there has been interest in whether they support the reorganization of activity for more effective collaboration among learners. Data have consistently shown that computer-based technologies can enhance activities where students work together, supporting on-task behavior on problems ranging from programming to writing to multimedia production. However, studies have also shown how complex it is to structure successful collaboration in schools—activities where students genuinely subdivide tasks and share knowledge rather than doing the same activities in parallel but clustered in a group (Hawkins & Sheingold, 1986).

Successful integration of technology uses it to advantage for group work, as in the Dalton and Charlotte schools. It can enable groups to work together more successfully by sharing common tools, by public display of work, supporting group products, and easy revision. Communications technologies can also alter traditional assumptions about learning relationships. Local and wide-area networks can support collaboration over time and distance. School-based experiments with these technologies have demonstrated effective distributed collaboration. Students and teachers can create and use common databases, work with each other on joint projects around the country and the world, and consult a broad array of experts and mentors for their work.

An elementary school in Ontario has been the site of an experiment in collaboration supported by LAN technology. The CSILE (Computer Supported Intentional Learning Environments) project has created a core of networked software tools that enables students to create a shared database about complex topics like the environment (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). Students enter their questions, findings, ideas, and reports into the database; they can read, comment, and draw on each others' efforts. The active network-based exchange engages students more deeply and frequently in the reflective thinking, interaction, and substantive judgment that supports the learning of thoughtfulness.

Extending the time, space, and disciplines across which collaboration can take place through LANs has some interesting consequences. Traditionally, assignments are completed, and the work and thought surrounding them disappear; work done in the 50 minutes of one classroom has no relationship to the topic or assignment discussed down the hall, or beyond the school walls. In one New York middle school, a central server and workstations distributed throughout the school encouraged students to see that their work in one subject was relevant to another. Science writing was used in English class; mathematics tools found their way into science projects. Students' work also began to have a longer active life span. When their completed projects were maintained as active files, students and teachers became aware that this student-generated database was a resource that could be used by the authors and others throughout their careers (Newman, in press).

Wide-area networks have also shown powerful potential to affect the organization of schooling.[3] Well-conceived software and activities allow students to share scientific data and their analyses, to have extended discussions with distant peers and mentors, to collaborate in producing newspapers and journals (Hawkins, 1991; U.S. Office of Technology Assessment, 1989).

The infusion of technology into collaborative learning can help to replace the view of learning that composes subject matter into consumable chunks with a view of knowledge as a network of ideas, information, interpretation that must be exercised and revised as an alive and interconnected body through sustained exchange with others.

One of the central qualities of reorganized schooling positions teachers as mentors—moving fluidly among roles of lecturer and seminar leader, through individual diagnostician and coach. Technologies can

[3] Technical Education Research Centers (TERC), Cambridge, MA, and Margaret Riel, AT&T Long Distance Learning Network, San Diego, CA.

help to make this differentiation of roles possible.

In an interesting experiment in a public high school in Pittsburgh, an intelligent tutoring system for learning geometry proofs (GPTutor) was tested to see how it fared in the classroom environment and to provide data for modifying the system. Students worked individually with computers in a revised mathematics curriculum that made central use of this resource. It was demonstrated that students were much more engaged in their mathematics work in this context (they came early, got to work immediately, and stayed late), and they learned well. But a surprising—and very powerful—finding was the change in the teacher's instructional role. He began to provide much more individualized, targeted help to students; unlike his previous whole-group instructional methods, he began to spend more time with the weaker students. He also found that he began to value—and credit—process and effort in the work in addition to final answers (Schofield, 1989). These changes in the ways that students and teachers spent time together in work, supported by technologies, were credited as central to improved learning outcomes. In this way, technologies are thought about as creating more efficient learning environments, not by decreasing numbers of staff but by improving learning through more efficient compositions of relationships between students, teachers, and resources.

One of the severe problems of today's schools is the isolation of individual teachers within their own classroom walls. It is the rare school where teachers are provided with the time, tools, and requirements to work together, or for sustained professional growth. Time to plan collectively or to create and explicitly coordinate the interdisciplinary links that are basic for reorganized schooling is very rare. LANs have demonstrated how distributed technologies can provide new capacities for teachers to coordinate activities, changing some of the rigid space and scheduling constraints. But LANs to support planning and coordination are far from the norm in schools.

In addition, it is now a world that is pressing educators to look beyond their individual schools. Effective professional development requires sustained conversation with experts and peers over time and space, incorporating well-developed materials and examples and images of good practice that can be tried out and discussed.

Exploration with telecommunications to create different forms of interaction for educators is beginning to define characteristics of productive use. For example, the Mathematics Leadership Project at Bank Street College has supplied laptop technology and modems to teachers who participate in an intensive summer institute for mathematics educators and then return to their schools. The communications technology links these teachers throughout the school year to each other and to expert advisors. The network is the best medium for the sustained, specific, informal, and comparative conversation about classroom life that is crucial to changed practice. The advisors and students consult each other on a variety of issues (Honey & Hupert, 1992).

While telecommunications capacities have been relatively well absorbed by other professional groups, they are just beginning to be used by significant numbers of educators (Honey & Henriquez, in press). As the variety and reach of telecommunications pipelines expands, the ways in which they are designed for the purposes of supporting school change require extensive experimentation. Simply hooking teachers to a network is insufficient; engaged discussion and sharing of images with peers at a distance needs to be carefully structured as a *social organization* of technology use for professional growth.

New school designs that embed technology in active learning challenge prevailing modes of assessment of what students know, both for broad accountability purposes and individualized diagnosis by teachers. New methods are now being vigorously explored, notably performance-based and portfolio assessments. These new methods require extended student work on complex tasks, embedding assessment in the curriculum. This has unintended consequences for the organization of schools because it requires people to change their long-held assumptions about the social organization of testing. Traditionally, testing is understood to be isolated from the curriculum, carried out in a different time and place, and with perhaps a different adult supervisor, than is day-to-day learning. When testing is merged with the curriculum, teachers, students, and parents are initially confused and unsettled about whether and how we can be assured that they—the students—have learned.

At Brooklyn Technical High School, in New York City, the head of the mechanical-engineering department has substantially reorganized the curriculum to focus on project-based group work.[4] Students are given the basic scientific, mathematical, and technical concepts and tools in intensive seminars, and spend much of their time on design problems. Students are given design specifications and criteria for judging quality, and are encouraged to take conceptual risks. The assessment of their work consists of a "portfolio" that includes a written group log, which must describe the decisions made and the group dynamics of the work process; an individual design notebook, which features their struggles with problems and decisions; a written report; a presentation to the class of their design and rationale, which is attended by outside professionals who query and rate the students on their work. Technology (computers and video) supports the production of the documentation for assessment purposes. This approach to assessment requires shaping of daily learning experiences to provide for teacher diagnosis of student understanding, and public accountability.

[4] Center for Technology in Education Videotape, Assessment and Technology and accompanying materials; also, contact Ed Goldman, Mechanical Engineering Department, Brooklyn Technical High School, Brooklyn, NY.

Reorganization Takes Time

Reorganizing schools for thoughtfulness presents surprises and difficulties to teachers, administrators, and research teams. It is neither short term nor simple. In our experience, a commitment of three to five years of planning and revision is required to significantly alter schooling conditions in ways that deeply incorporate technologies. Used well, technology presses for longer and more flexible work periods, more complex relationships among the disciplines in learning, the creation and maintenance of considerably more diverse and personal relationships in and outside the school, and activity structures which necessitate management skills unfamiliar to many.

For technology to be used well in schools, we can no longer view it solely from the perspective of individual-machine learning interactions. Technologies must be viewed as a resource for reorganizing schooling—from initial planning for change—so that teachers and students interact and participate more substantially with materials, with each other, and with the worlds outside of schools.

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