tional, and cultural obstacles are discussed regularly. However, the characteristics of internetworking technology—distributed, heterogeneous, nonhierarchical, open access, evolutionary, standards based—appear to map very well onto goals and processes of educational reform.

We have a window of opportunity. The national and international communications and information infrastructure is being engineered and deployed at the same time as new structures are sought for education. The federal agencies involved in the development of the National Research and Education Network (NREN) are already contributing to the technological state of the art and internetworking infrastructure. This includes DARPA, NSF, DOE, NASA, HHS/NIH, DOC/NOAA, EPA, DOC/NIST [2]. The NSF has a lead role in the deployment of the NREN as well as research on gigabit bandwidth. The NSF Education and Human Resources Directorate is also actively involved in research and development of educational applications of the NREN [4]. Federal agencies are in various stages of adopting and implementing internetworking and related standards for networked information services. A small but growing number of persons and organizations are calling for federal agencies to make their projects, data bases, products, and services available through the Internet.

Individual states and school districts are also in various stages of planning and deploying networking and information infrastructures and services for access by learners and teachers (among other public sectors such as libraries, agriculture, and health services). For example, the Texas Educational Network (TENet) is planned to be accessible by all teachers in Texas public schools. This network provides access to many internetworked resources within and outside of Texas, and is a key mechanism in the Texas State Systemic Initiative for science and mathematics education reform. Many commercial information utilities such as America Online and nonprofit networking communities such as FrEdMail, FidoNet, and National Public Telecommunications Network have established at least an electronic-mail level of connectivity with Internet, and they all are used at least partly for learning and teaching activities, formal and informal.

The prospect of a new *educational* system evolving along internetworking lines will likely depend primarily on how compelling the learning outcomes are perceived to be as a consequence of the innovations in learning and teaching that take advantage of the connectivity, collaboration, and distributed resources. If a larger proportion of promising educational reform efforts both take advantage of and contribute to internetworked resources, then educators, parents, and taxpayers can evaluate the benefits of this model and make informed decisions about investment in and design of the new information infrastructure. ■

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Systems & Designs

DESIGNING THE NEW AMERICAN SCHOOLS

Robert Pearlman

Eleven design teams are now at work developing designs for the new generation of American schools under grants from the New American Schools Development Corporation (NASDC). These designs will be implemented at scores of sites around the country over the next two years.

These design teams would benefit greatly by adopting and adapting the experience of those exemplary innovative schools launched in this country during the past five years. Many of these schools started with an assumption that technology would play a major role, but that first the curriculum, school organization, and learning environments would have to be changed to more fully exploit the role technologies could play.

The easiest lesson to grasp from a decade of significant infusion of technology into American schools is that technology by itself does not transform schooling. Horror stories abound of new technology-intensive facilities failing to remake classrooms. The *Wall Street Journal* (Nov. 23, 1992) calls the new Stuyvesant High School in New York City a "computer nerd's dream but an educator's quandry." It also complains that the technology fails to "cut costs or improve productivity."

Changing schools requires changing all elements of school practice and organization simultaneously—school organization, curriculum, assessment, technology, and the learning environments.

- *School Organization.* Large schools and their isolated classrooms have to be broken down and recombined into smaller cluster communities that provide more personal environments for children and self-managing work teams for teachers.
- *Curriculum.* Teacher-talk, workbooks, and make-work academics have to be replaced by meaningful and authentic short and long-term project work by students.
- *Assessment and Accountability.* A personal growth system needs to be created to help students, parents, *and* teachers set goals, plan, monitor, and assess a student's evolving performance through real products, presentations, and exhibitions of their work. School accountability, in turn, should shift from basic-skill multiple-choice tests to new performance-based tests and other high-performance indicators.
- *Technology.* With a change in learning and teaching toward project work, technology should be made ubiquitous in the school building and community to provide students and teachers with the tools to do their work and to communicate and collaborate with one another and with similar-minded collaborators throughout the world.
- *Learning Environments.* Schools where students and teachers are workers require learning environments designed more like workplaces, with spaces that are workrooms, work areas, seminar rooms, and conference rooms.

We have learned a great deal about technology utilization in K–12 education in the past decade. The applications that most successfully support new forms of learning and teaching are productivity tools that help students and teachers do their work. These include word processors, software products like HyperCard, Linkway, and HiCE Media Text that allow students to make new kinds of documents combining text, graphics, and video, multimedia stations for publishing and for making videos, telecommunications to connect kids and teachers to collaborators in doing real science and in sharing writing and other communications. Other technology applications that spur cooperative learning and higher-order thinking include discussion stimulators and group activity generators.

Project work and the appropriate application of technology tools require work spaces, work areas, work rooms, and specialized discussion and seminar rooms. Schools must stop resembling egg crates of standard-sized rooms. Schools now need to house both large and small work spaces more appropriate to the new learning tasks and activities, and more appropriate to students who are working collaboratively and individually on their projects and products.

Two schools that serve as excellent design examples for this new generation are South Pointe Elementary in Dade County, Fla., and the Saturn School of Tomorrow in St. Paul, Minn. (Saturn was the school former President George Bush visited in 1991 to announce his New American Schools proposal.)

Key for a restructured school to be built or remodeled is a school-based team with a shared educational vision that can lead to an innovative educational design, facility design, and the right application of technology to support the vision. Dade County public schools (Miami) solicited these shared innovative visions by being the first school system in the country to issue a national Request for Proposals (RFP) to design the first seven of 49 new schools that Dade would build over the next five years.

The Saturn School Project—Dade's effort to recruit the best ideas—is a partnership of the school board, the superintendent, and the teachers union. All agreed the new schools should be redesigned, educationally and physically, from the ground up. By the fall of 1992, ten Saturn schools had opened in Dade, and a new cycle of RFP's had been issued.

South Pointe Elementary School opened in September, 1991, based on the Tesseract School model from Education Alternatives Inc., an organization running an innovative private school in Minneapolis. The Tesseract model stresses active learning in every subject and true ownership of learning by students. Teachers work with students to "plan, do, and review" their learning activities. Teachers are gentle and nonintrusive and work with students to learn how to learn, and learn how to make choices.

No subject is fragmented—it is whole language, and whole social studies. No workbooks or xerox sheets are used. Students work together, learn about each other's learning styles, confer, and review and make presentations. Education is personal. Every student at South Pointe has a "mentor," either a parent or a recruited senior citizen. Teachers, mentors, and students together develop the student's personal education plan.

Several national articles on South Pointe have stressed the unique situation of the private firm being contracted to manage a public school. But it is seriously misleading to view South Pointe as a privatization-of-public-education story. Rather, it is a story of innovative Dade public school educators managing a school while buying training, consultation, and support from a company with a unique, "child-centered" vision. Education Alternatives, Inc. (EAI), however, changed their business orientation in September, 1992, when they contracted to directly manage nine public schools in Baltimore.

Prior to opening, the Principal and

Lead Teacher of South Pointe recruited 25 Dade teachers who shared the school's vision, of more than 400 who applied, and lead them in Tesseract training. Working with architects, they recast the new building design to create a facility designed for community and for the whole child. The K–6 school of 500 students is divided into four K–6 "communities" of approximately 150 students each. Each community occupies one distinct half-floor wing of the two-story building. At South Pointe each K–6 community meets for 10–15 minutes every morning, so each community space is designed with sliding walls to facilitate community meetings. And because teachers and students stay with the community for the student's K–6 years, the sliding walls and large rooms facilitate teacher teaming and collaboration and joint activities among classes and groups within the communities.

Technology is mainly distributed in classrooms so that students can use these tools to do their own projects. Teachers use technology to take and keep notes on student learning styles and activities. Classrooms are large in order to accommodate a large variety of student work spaces. There is a technology lab at the school, but it is an open-access walk-in room with multimedia publishing and video-producing stations staffed by a paraprofessional who assists the student workers.

Both the St. Paul Saturn School and Dade's 49-school Saturn School Project had been inspired in the late 1980s by American Federation of Teacher's President Albert Shanker challenge to create schools where "labor and management threw away all their assumptions about how to manufacture an automobile and sat down together to design the process afresh."

St. Paul Saturn's vision was started in 1987 by a working group and included prospective parents and partners such as the St. Paul Federation of Teachers, the University of St. Thomas, and MECC, the largest K–12 educational-software company in the world.

At Saturn, students (grades 4–8) confer with teachers and parents to construct their own personal growth plans. Textbooks are nonexistent. Saturn is located downtown so that student minicourses and projects can take full advantage of the cultural and business institutions and human resources there. Director Tom King says Saturn students learn "new skills for a changing world: global communications, personal wellness, mentorship/apprenticeship, and community service activities, cooperative learning, project-based work, videography."

What is remarkable about the Saturn experience is that the team, including the director, teachers, and parents had an opportunity to first create the new learning environments at a temporary site and try them out and revise them over a year and a half. It was this unique practical experience that made it possible with them to work with architects to design the learning spaces now located in a remodeled YMCA.

Thus the Saturn site looks nothing like a school. Instead it looks like a series of work rooms, work spaces, work areas, specialty work rooms, offices, and large and small group discussion rooms. Walk the halls of Saturn, and you will see work areas: a writing and desktop publishing center, a lego-logo robotics area, several integrated learning systems and MECC network areas, and spaces and stations throughout all rooms and corridors for small group activity and projects.

The few self-contained classrooms are actually terraced discussion rooms using *Discourse,* a technology which links response terminals throughout the room to a central computer and large-screen terminals and a videodisc presentation system for student- and teacher-led discussions. The microcomputer displays the responses as well as group polling information and charts on a large screen monitor or projection device and also controls a videodisc player. Saturn teachers say that any subject can be taught using the Discourse system.

Technology is everywhere at Saturn, and all rooms and work areas are linked to a central computer network and video distribution system. But the key to technology utilization at Saturn is that the kids and teachers have the technology tools to do their work, and the curriculum is designed to engage students individually and cooperatively in short- and long-term projects.

In our efforts to design the Co-NECT School, we are attempting to learn from the experience of South Pointe Elementary and the St. Paul Saturn School of Tomorrow, as well as from 10 other innovative schools across the country that were launched in the past few years.

Co-NECT stands for "Cooperative Networked Educational Community for Tomorrow." It is a K–12 design that enables local communities to create their own "break-the-mold" schools that will bring together students, teachers, parents, administrators, and community leaders in new social arrangements to work with a radically transformed curriculum with the support of dramatically intensified use of technology.

The Co-NECT School design concept has three key components:

- A **restructured school community,** featuring self-managing "clusters" of students, teachers, administrators, and community members.
- A radically transformed **project-based curriculum** based on long-term investigation of meaningful and challenging topics, supported by in-depth **seminars** in which students come to have deep understandings of key concepts in all subject areas while developing critical work skills including self-direction, perseverance, and commitment to quality.
- A flexible and open computer-based **communication network** that supports the restructured school community and the project-based curriculum by connecting all school community members with each other and to a rich array of local, national, and global learning resources and by permitting intensive use of the best available technological resources.
- Besides these components we are developing a personal-growth system for student assessment and school accountability and working with architects to design models for the new

learning environments that will be needed by students and teachers working together in a Co-NECT School. ■

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Systems & Designs

SCHOOL NETWORKS: DELIVERY OR ACCESS

Denis Newman

Computer networks hold the key to the large-scale implementation of school technology. Choices being made in the design and functions of networks will constrain the resources delivered to teacher and student desktops. More importantly, they will also decide the feasibility of developing the kinds of communities that can support new, innovative ways of teaching and learning. Painted in the broadest strokes, the choice is between systems that *deliver* traditional instruction from a central repository and systems that enable teachers and students to *access* and gather information from distributed resources and communities of peers. For example, will a high school teacher who is learning to make the most of a new simulation of the cardiovascular system for biology class be able to communicate with peers who are trying to do the same thing, or will the network be designed simply to deliver cardiovascular courseware to the workstations of the students?

Delivery vs. Access

The delivery approach can be traced to the instructional paradigm that has dominated school computing from the first computer-assisted instruction programs to advanced intelligent tutoring systems. The associated pedagogy puts the student in a passive role of a receptacle for information. Often the instructional goals tend toward the basic skills, the usual items found in standardized tests. Individualization is the major contribution of the technology, and the students are isolated from peers (advertisements often show students wearing headsets) and from other resources such as remote databases that are necessary if students are to become involved in inquiry skills or open-ended real-world tasks not addressed well by the standardized tests.

The access approach is consistent with a pedagogy that puts the learners in an active role in exploring complex problems and favors constructing collaborative environments. Often the computer becomes a tool or a stimulus for projects that let students delve deeply into subjects and example problems. A simulation of the cardiovascular system makes a very complex system accessible to the classroom. Networks in this approach are channels for obtaining more information about that system, more peer collaborators, and additional materials that will help make most of the simulation available at the desktop.

Networks are needed if innovative technology is to be disseminated widely. Large-scale decisions about technology at the national, state, or school district level usually involve networks. Deciding whether these are optimized for delivering basic-skills courseware or for giving students and teachers access to resources for more open-ended school work is the major battleground currently in the struggle between these approaches.

Dissociation of Local and Wide Area Networks

We find the distinction between delivery and access at the heart of the strange dissociation in schools of local area networks and wide area networks. In schools, LANs and WANs have distinct functions. A study conducted by Bolt, Beranek and Newman (BBN) attempted to find out how schools are connecting their LANs to WANs such as the Internet. Building on our company's network-engineering expertise as well as experience in educational technology, we obtained funding from the National Science Foundation to help address the concern that unless schools can make use of LANs for access to WANs, government investment in a national school network will have little impact [2].

One step in this research was to follow up on a 1989 California Technology Project survey that had identified schools with LANs and schools with some kind of modem connection. We identified the intersection of these schools, since these, we thought would be a good sample to start our investigation of connecting LANs and WANs. However, *none* that we were able to contact by phone had any connection between their instructional LAN and the modem. When used for instruction in schools, a computer-with-modem device is essentially a standalone device, often found in a classroom that the school LAN does not reach.

The separation of the functions is not just a technical matter. It comes down to the distinction between the delivery and acccess approaches to school technology. School LANs are dominated by the *integrated learning systems* (known as ILSs) that have evolved from the time-sharing CAI delivery systems of the 1970s. ILSs are sold usually as a lab consisting of enough computers for each student