Education and Technology: Future Visions

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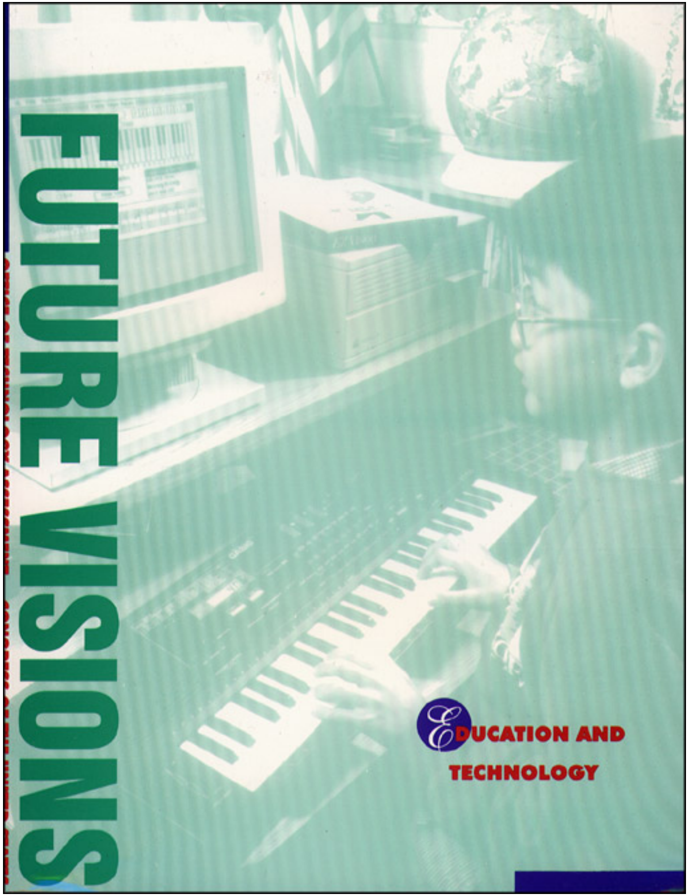

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Foreword

Computers, telecommunications networks, and other technologies have become increasingly central to the American way of life. The nation's schools are also investing substantially in technologies for education. What will be the impact of these technologies on schools in the near future? Will there be dramatic changes in teaching techniques, curriculum, staffing, and even the concept of school as a result of investments in these tools? What kinds of visions can we foresee for education over the next decade, if technology use is supported? What factors affect the likelihood of meeting these visions? What role might the federal government play?

In the fall of 1994, the Office of Technology Assessment (OTA) commissioned five contractors to write papers dealing with these issues. In June 1995, the contractors and a number of other prominent educators were invited to OTA for an all-day workshop to discuss these papers and the issues more broadly. This background paper summarizes the workshop discussion and contains the commissioned papers in their entirety. OTA gratefully acknowledges the contributions of the individuals who participated in these efforts.

ROGER C. HERDMAN
Director

Project Staff

Clyde J. Behney
Assistant Director, OTA

Denise Dougherty
Program Director
Education and Human Resources

PRINCIPAL STAFF

Kathleen Fulton
Project Director

Isabelle Bruder-Smith
Analyst

Ethan T. Leonard
Research Analyst

Kathleen McCormally
Research Assistant

ADMINISTRATIVE STAFF

Rebecca Erickson
Office Administrator

Linda Rayford
PC Specialist

Nanette Rushing
Secretary

CONTRACTORS

Nancy Kober
Editor

Madeline Gross
In-House

Workshop Participants

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Ted Kahn, ***Workshop Chair*** *
Institute for Research on Learning

Jonathan Betz
Thomas Jefferson High School Senior

James J. Bosco*
Western Michigan University

Luyen Chou
Learn Technologies

Larry Cuban
Stanford University

Christopher Dede
George Mason University

Bruce Goldberg
Bolt Beranek and Newman

Nancy Hechinger
Industry Consultant

Beverly Hunter*
Bolt Beranek and Newman

Robert Kozma*
SRI International

Matthew W. Lewis
The RAND Corporation

Stephen Marcus*
National Writing Project Technology Network

Arthur Melmed*
George Mason University

David Mintz*
National Center on Education and the Economy

W. Curtiss Priest
Center for Information Technology and Society

Margaret Riel*
InterLearn

Richard Wertheimer
Pittsburgh Public Schools

*These individuals also reviewed the background paper.

Contents

Education and Technology: Future Visions

BACKGROUND FOR THIS STUDY

Several times over the last decade, Congress has asked the Office of Technology Assessment (OTA) to examine the status of technology in American education from various perspectives. In the 1988 study *Power On! New Tools for Teaching and Learning*,[1] OTA looked at the use of computers and other technologies in K-12 schools. In the 1989 study *Linking for Learning*,[2] OTA focused on distance learning technologies, including improvements in their affordability, flexibility, and educational applications. In the 1993 study *Adult Literacy and New Technologies*,[3] OTA looked at technologies for providing literacy instruction to adult learners. And in the 1995 study *Teachers and Technology: Making the Connection*,[4] OTA examined how teachers learn about and use technologies and how various technologies can help teachers improve their teaching and grow professionally.

Although each of these studies gave some attention to new or emerging technologies and factors affecting their adoption, the

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[1] U.S. Congress, Office of Technology Assessment, *Power On! New Tools for Teaching and Learning*, OTA-SET-379 (Washington, DC: U.S. Government Printing Office, September 1988).

[2] U.S. Congress, Office of Technology Assessment, *Linking for Learning: A New Course for Education*, OTA-SET-430 (Washington, DC: U.S. Government Printing Office, November 1989).

[3] U.S. Congress, Office of Technology Assessment, *Adult Literacy and New Technologies: Tools for a Lifetime*, OTA-SET-550 (Washington, DC: U.S. Government Printing Office, July 1993).

[4] U.S. Congress, Office of Technology Assessment, *Teachers and Technology: Making the Connection*, OTA-EHR-616 (Washington, DC: U.S. Government Printing Office, April 1995).

studies focused primarily on the present, not the future. But as technology advances more and more rapidly, the future seems to arrive ever more quickly. Decisions currently facing Congress about telecommunications policies, funding for education, and education program continuations and consolidations will have impacts on schooling that could last several years, or even decades. To make wise decisions, it is important that Congress consider the long-range potential and impacts of technologies for education. Where is the nation's educational system headed, how will we know when we get there, and what opportunities or difficulties may lie along the road?

In keeping with its role as an "early warning system" for Congress, OTA commissioned several papers on the topic "Technology Trends and Their Impacts on Teaching in the Future." OTA asked the authors of the commissioned papers to consider future visions of schooling over the next five to 10 years, taking into account recent trends in technology, school reform, student demographics, and telecommunications regulation. What might schools of the near future look like? Which factors or incentives will influence the direction of change? What might be the positive and negative implications of different future scenarios? What are the roles of the various players in the educational system? How can schools help shape technology decisions to acquire the resources they need? How might the federal government help achieve the most promising of these visions?

In response to OTA's request, five contractors prepared papers in the fall of 1994. Each took a slightly different approach to envisioning the future of education:

- James Bosco's paper, "Schooling and Learning in an Information Society," reviews the historical impact that various developments in communications have had on learning. Bosco also examines past changes in the institution of the school and, rather than sketching a scenario, discusses the effects of technology on learning inside and outside of school, today and in the future.
- "Learning and Teaching in 2004: The Big Dig," by Beverly Hunter and Bruce Goldberg, lays out a scenario in which students, teachers, and the entire Boston community develop an extensive body of learning experiences based on an actual, major urban construction project, the Central Artery Tunnel Project, currently slated for completion in 2004. Hunter and Goldberg envision fundamental changes in the nature of schooling and lifelong learning and describe how technological applications can bring together school, work, family, and neighborhood in new learning environments.
- Margaret Riel's paper, "The Future of Teaching," is told through the voices of educators in 2005 as they explain their school's philosophy and program to the district's quality review team. The paper describes a new school organizational and physical structure, explains how technologies support this system, and addresses staffing, educational, and community concerns.
- "Year 2005: Using Technology to Build Communities of Understanding," by Robert Kozma and Wayne Grant, uses scenarios to tell the story of a "community of learners" from three perspectives—connections from school to the outside world, to the workplace, and to the home—and analyzes the social, pedagogical, and technological implications for each perspective as demonstrated by the scenarios.
- Larry Cuban's paper, "Public School Teachers Using Machines in the Next Decade," discusses three possible outcomes of technological integration in schools: that of the technophile, the preservationist, and the cautious optimist. Cuban assesses the likelihood of each occurring and discusses the basis for his prediction.

To supplement the information and ideas in these papers, OTA convened a workshop on June

9, 1995, on the topic "Education and Technology: Future Visions."[5] At this workshop 17 educators and researchers, including the authors of the contractor papers, met with OTA staff to explore in more detail the issues raised in the five papers and to discuss other future scenarios and their policy implications. Also discussed at the workshop was a sixth paper, by Chris Dede and Matt Lewis, entitled "Assessment of Emerging Educational Technologies That Might Assist and Enhance the School-to-Work Transition."[6] Although this paper was written for OTA's assessment *Learning to Work: Making the Transition from School to Work,*[7] it is also relevant.

This OTA background paper synthesizes the major themes and ideas from these futures papers and the workshop discussion. It summarizes the views of the contractors and workshop participants about possible future visions of schooling over the next decade. The paper considers technology and school reform in the context of the demands of the information age, changing views of learning, and conflicting roles of schools. It considers some key issues for these future visions, including changing curriculum and assessment, changing roles for teachers and staff, an expanded view of community, and considerations associated with the potential negative impacts of technology.

This background paper does not endorse any particular vision. Instead it analyzes various factors likely to influence the different future scenarios and lays out possible courses of federal action and potential state and private roles as discussed in the papers and workshop.

SUMMARY OF KEY POINTS AND WORKSHOP DISCUSSION

- Many factors are pressuring schools to make substantive reforms in curriculum, organization, and teacher roles. Employers are calling for individuals who can manage large amounts of information, solve complex problems, adapt to changing requirements with flexibility and creativity, and work in teams.[8] New research on learning supports school environments in which students can acquire advanced skills and knowledge by working on meaningful problems.[9] And parents, business, and students—the "consumers" of education—are asking schools to fill many roles, yet expressing dissatisfaction with how schools are carrying them out.
- Technology can be an impetus for major school reform or an instrument for making the current school system more efficient and productive. Many educational futurists advocate seizing

[5] See page v for the roster of workshop participants.

[6] Chris Dede and Matthew Lewis, "Assessment of Emerging Educational Technologies That Might Assist and Enhance the School-to-Work Transition," OTA contractor report, May 1995.

[7] U.S. Congress, Office of Technology Assessment, *Learning to Work: Making the Transition from School to Work*, OTA-EHR-637 (Washington, DC: U.S. Government Printing Office, September 1995).

[8] See, for example, *What Work Requires of Schools*: *A SCANS Report for America 2000,* Secretary's Commission on Achieving Necessary Skills (Washington, DC: U.S. Department of Labor, June 1991); William B. Johnston and Arnold H. Packer, *Workforce 2000: Work and Workers for the 21st Century* (Indianapolis, IN: Hudson Institute, 1987); Anthony Patrick Carnevale, *America and the New Economy* (Washington, DC: The Program and Freedom Foundation, 1994); Committee for Economic Development, *Connecting Students to a Changing World: A Technology Strategy for Improving Mathematics and Science Education* (Washington, DC: Committee for Economic Development, September 1995); Lawrence Mishel and Jared Bernstein, *The State of Working America* (Armonk, NY: M.E. Sharpe, 1994).

[9] See, for example, Ronald D. Anderson et. al., *Issues of Curriculum Reform in Science, Mathematics and Higher Order Thinking Across the Disciplines* (Washington, DC: U.S. Government Printing Office, January 1994); Barbara Means (ed.), "Using Technology to Advance Education Goals," *Technology and Education Reform* (San Francisco, CA: Jossey-Bass Publishers, 1994); and Joan Bissell et. al., "National Geographic Kids Network and Language Minority Students (Irvine, CA: University of California, Department of Education, July 1994).

the former opportunity, suggesting that major reform is required and that technology offers a unique and powerful resource to bring about such change.

- One of the most promising aspects of technology for education is how it can link schools, homes, workplaces, and neighborhoods into innovative communities that value learning and offer rich learning experiences. This enhanced network of human resources that can participate in educating students may be the most significant technological offshoot. As the institutional framework shifts from an emphasis on "schools" to one on "learning communities," and as learning is distributed across multiple locations, questions about education governance and the traditional school structure will need to be addressed.
- Technology teaching and learning tools allow students and their teachers to contribute to the information base with their own research and products. If teachers and students are considered not just consumers of information but also creators of information, new opportunities could be made available for funding educational activities through the products and services they provide to the broader community.
- Schools and communities will have to confront concerns about the "down side" of technology, including possible reductions and changes in teaching staff, disparities in technology access, potential exposure of students to harmful material, and a de-emphasis of traditional instructional methods that work well for some children.
- The federal government's role could be most important in articulating a vision of how technologies can support improved communities of learning. Federal support could take the form of seeding innovation, showcasing the most promising local initiatives, and helping to cross-pollinate the best practices. Telecommunications and other technologies can themselves be resources for showing, sharing, and discussing innovation. Support from all segments of society, public and private, will be required if these resources are to be made available to all learners regardless of location or economic situation.

TECHNOLOGY AND SCHOOL REFORM: SETTING THE CONTEXT

The future visions discussed in most of the papers and at the workshop assume a strong and symbiotic relationship between educational technology and educational reform. The contractors and workshop participants view technology not so much as a means for making the existing education system more productive or efficient than as a means for encouraging and facilitating broader reforms in school structure, curriculum, teaching, and learning. Schools grappling with how to incorporate technology and how to encourage teachers to use it effectively can treat these primarily as engineering challenges—which can be remedied with more equipment and training—or, as the OTA commissioned papers suggest, as school design and organization challenges to be remedied with substantive reforms. They maintain that technology creates an impetus for major transformation in the institution of schooling, and it also offers new tools for carrying out this transformation in ways not possible before.

Several forces are converging to encourage school reform though technology. These include: demands and tools of the information age, changing views of learning, and the conflicting roles of schools.

Demands of the Information Age

A major driving force in school reform is the transformation of the American economy from one based on industrial production to one based on information creation and exchange. In their paper, Dede and Lewis describe this change:[10]

[10] Chris Dede and Matt Lewis, op. cit., footnote 6.

> In the past, preparing learners to compete effectively with other Americans in our domestic economy was sufficient to ensure their prosperity. However, the evolution of world-wide markets means that U.S. employers and employees must be more adept than their global competitors at meeting the needs of a very diverse range of customers. In this new economic "ecology," each nation is seeking a range of specialized niches based on its financial, human, and natural resources. Developed countries, which no longer have easily available natural resources and cheap labor, have difficulty competing with rising-star developing nations in manufacturing standardized industrial commodities. However, America is utilizing her strengths (technological expertise, an advanced industrial base, and educated citizenry) to develop an economy that uses sophisticated people and information tools to produce customized, value-added products.

In the popular book *Future Shock*[11] and subsequent works,[12] futurists Alvin and Heidi Toffler use the metaphor of waves to describe the historical transformation of American society from an agricultural society (the First Wave), to an industrial one (the Second Wave), and most recently, to an information society (the Third Wave)—each a revolution of major proportions. Many, including some of the OTA authors and workshop participants, would agree with the Tofflers' view that the current school system, with its factory-like organization and inflexible boxes of space and time,[13] is a vestige of the Second Wave industrial society and is quickly becoming outdated by the Third Wave technological world. Without major reforms in school organization and missions, they maintain, schools will continue to prepare students for a world that no longer exists, developing in students yesterday's skills for tomorrow's world.

A shift to Third Wave schooling is reflected in the kinds of institutions described in most of the contractors' scenarios. These new kinds of schools have a "flat" organizational structure, whereby clusters of teachers and students work in groups on substantive group projects, bringing in information and expertise from resources outside the organization, with more shared responsibility for decisionmaking and initiative—a stark contrast to the closed, bureaucratic, hierarchical structure found in many of today's school districts, buildings, and individual classrooms with their production line approaches to education.

Developing Views of Learning

Other influences on school reform and the adoption of new technologies are emerging views from research about how children learn. Increasingly, attention is being paid to one strain of cognitive theory known as *constructivism*, a view that:

> . . . advanced skills of comprehension, reading, composition, and experimentation are acquired not through the transmission of facts but through the learner's interacting with content. This *constructivist* view of learning is the wellspring of ideas for many of the current curriculum and instruction reform efforts, calling upon schools to teach basic skills within *authentic* and, hence, more complex contexts in order to model expert thought processes and encourage the use of collaboration and external supports so that students thus can achieve intellectual accomplishments they could not attain on their own.[14]

Authentic learning is emphasized in the scenarios presented in several of the commissioned papers. Hunter and Goldberg describe what they mean by *authentic instruction*:[15]

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[11] Alvin Toffler, *Future Shock* (New York, NY: Random House, 1970).

[12] Alvin Toffler, *The Third Wave* (New York, NY: Morrow, 1980); Alvin and Heidi Toffler, op. cit., footnote 8.

[13] See, U.S. Congress, Office of Technology Assessment, *Teachers and Technology,* op. cit., footnote 4.

[14] Barbara Means (ed.), op. cit., footnote 11, p. 5.

[15] Beverly Hunter and Bruce Goldberg, "Learning and Teaching in 2004: The Big Dig," OTA contractor report, November 1994.

- Working on projects and problems of intrinsic interest to the learner or a group of learners, rather than learning what everyone else of the same age is expected to learn at the time.
- Working in a hands-on mode with the physical and social world, in addition to and in interaction with abstract symbols and words and electronic representations.
- Learning something at the time a learner is ready and motivated to learn it—perhaps because it is needed to solve a problem or complete a project, or perhaps just from developmental readiness, or curiosity, or social pressure—rather than in a preset curriculum sequence.
- Continual learning.
- Learning in an interdisciplinary context, rather than in separate subjects and isolated topics; working on a project in depth, rather than covering many topics superficially.
- Working directly with people from other places and cultures, rather than only indirectly through books.
- Learning through teamwork.
- Producing something of real value to someone.
- Using the real tools for intellectual work that are used in the workplace, rather than oversimplified textbook techniques.
- Basing assessment of student progress on performance of real tasks, rather than artificial tests.

Contructivism also takes advantage of the student's natural inclination to learn through experience and to "create mental structures. . .which organize and synthesize the information and experience which the individual encounters in the world."[16] Workshop participants discussed whether constructivism might just be another educational fad, but most agreed that the abilities to construct knowledge, value complexity, and solve complex problems are skills that all students will need to succeed in an information-based society. It was suggested that constructivism is flexible enough to co-exist with other instructional philosophies. As Nancy Hechinger said, "It's not either direct instruction or contructivism or collaborative [work] . . . we know a lot about learning and sometimes one is appropriate and sometimes another is appropriate."[17]

The importance of nurturing in children the kind of learning that they undertake naturally outside of school is not a new idea. Eighty years ago John Dewey said:

> What is learned in school is at best only a small part of education, a relatively superficial part of education; and yet what is learned in school makes artificial distinctions in society and marks persons off from one another. Consequently we exaggerate school learning compared to what is gained in the ordinary course of living. Rousseau was almost the first to see that learning is a matter of necessity; it is a part of the process of self-preservation and of growth. If we want, then, to find out how education takes place most successfully, let us go to the experiences of children where learning is a necessity, and not to the practices of schools where it is largely an adornment, a superfluity, and even an unwelcome imposition.[18]

Futurist George Leonard described learning as an "ecstatic" process that changes the learner.[19] Believing that this kind of learning occurs naturally, Leonard saw no reason why schools cannot produce "ecstatic education," a view shared by several OTA workshop participants who noted that their views of education had been strongly influenced by Leonard's work. These beliefs are central to several scenarios presented in the OTA commissioned papers.

Some reformers have taken these ideas to the extreme of suggesting that education can and

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[16] James Bosco, "Schooling and Learning in an Information Society," OTA contractor report, November 1994, NTIS No. 95-172227.

[17] Transcript of OTA workshop, June 9, 1995, p. 173.

[18] John Dewey, *School of Tomorrow* (New York, NY: E.P. Dutton & Co., 1915), cited in Bosco.

[19] George Leonard, *Education and Ecstasy* (New York, NY: Delacorte Press, 1968).

should occur independently of schools. Lewis Perelman, for example, suggests, "If learning is everything, everywhere, how do we confine it to the box of a classroom? We can't. Then what's the point of having schools at all? There isn't any."[20]

The commissioned papers and workshop participants rejected this concept, primarily because it ignores the teacher's role in guiding learning and helping students put their understanding in context. Furthermore, to say that schools are extraneous ignores other inherently valuable features of the institution of school and neglects the opportunities that schools provide for students to learn and work together as a community. Workshop participant Bruce Goldberg said, "We forget that schooling is a whole lot more about working with people than it is about working with ideas. . .the only value of an idea is in a community."[21]

Conflicting Roles of School

Throughout history, public schools have been asked to assume many social and cultural roles in addition to their academic functions. As one educator has stated, schools are "the mainstay of our publicly determined means of rearing our children . . . our all-purpose institution for children."[22] Over the years, schools have struggled to assimilate a large immigrant population into the American culture, prepare all students for the roles that they will play in society, and provide a level playing field for economic attainment through equal access to education. American schools have been remarkably successful in meeting these goals, considering the vast challenges involved.

Today, schools are being asked to assume still more responsibilities and are blamed unfairly when they cannot solve all social problems. Workshop participants identified the following important, but often conflicting, roles of schools:

- Custodianship—giving parents a safe place to send their children, a nurturing home away from home.
- Credentialing and work preparation—preparing graduates to meet the requirements of higher education and employment.
- Cultural conservation—transmitting the values and shared traditions of the society.
- Intellectual nourishment—producing people with well-rounded minds, a love of learning, and a sense of themselves as creative, lifelong learners.

These multiple and sometimes conflicting roles create tensions among educators who are having trouble satisfying any of them fully. Many suggest that schools are not fulfilling these roles when:

- children bring weapons to school and are shot on playgrounds;[23]
- American students no longer score at the top of international academic comparisons;
- high school and even college graduates find it difficult to find jobs using the education and skills they learned in school;
- individuals and communities cannot agree on a common set of values; and
- many children are no longer being challenged in school.

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[20] Lewis J. Perelman, *School's Out: Hyperlearning, the New Technology, and the End of Education* (New York, NY: William Morrow and Co., 1992), p. 55.

[21] Workshop transcript, p. 78.

[22] Patricia Graham, "Assimilation, Adjustment, and Access: An Antiquarian View of American Education," *Learning from the Past,* Diane Ravitch and Maris A. Vinovskis (eds.) (Baltimore, MD: The Johns Hopkins University Press, 1995), p. 4.

[23] See, for example, Office of Technology Assessment, *Adolescent Health*, OTA-H-467 (Washington, DC: U.S. Government Printing Office, June 1991); and U.S. Congress, Office of Technology Assessment, *Risks to Students in Schools* OTA-ENV-632 (Washington, DC: U.S. Government Printing Office, September 1995).

These perceptions exist in public discourse and the popular press and are causing many people to question the mission of schools today.

Workshop participants agreed that the protective, custodial function is often the most central of the various demands placed on schools. Today, with most parents holding jobs outside the home, schools are the places children go while their parents work. But as crime and violence have increased, infiltrating the schools in many communities, confidence in the schools' ability to provide quality care has dropped. As one workshop participant said, "They're not safe enough, and if you put in more metal detectors, that's not going to help it. And if [students] get to school and there is no social fabric within the school itself, the parents aren't going to believe in the inherent conserving guardianship, custodial nature of schools."[24]

Schools are also charged with providing students with the knowledge and skills they need to succeed after graduation. Education has long been the key to the American dream, and a high school degree a passport to a decent job. Increasingly, this is not the case, as even college graduates struggle to find jobs commensurate with their credentials. As the value of the educational credential becomes less clear or less potent, the educational system as a whole is called into question. James Bosco explained this dynamic as follows:[25]

> If they are there [at a university] because they believe that if they do it right and follow the rules, that somehow or other, good things happen as a result of this, then many of them are in for a very, very disconcerting realization. What happens when there is a growing realization that the currency that we issue in schools no longer has value?

This issue of diminishing value is even more a problem for the high school graduates who do not go on to college. There is widespread concern that many high school graduates do not possess the academic and entry-level occupational skills necessary to succeed in the changing U.S. workplace.[26]

Schools are also responsible for transmitting the social and cultural values of society, the customs and "rational myths" that define the community.[27] Today this is increasingly difficult, with so many different views of what our culture is, has been, or should be. As Robert Kozma observed, "The culture is becoming fractionated and so schools are going to be fractionated. There's less consensus and there's less impetus to move forward in some kind of systemic way."[28]

Finally, as discussed above, schools have a mission to help children learn, in the purest sense of the word—to acquire knowledge for its own sake, build good habits of mind, develop a passion for learning. This function of schooling has sometimes taken a back seat to others.

Questions of educational reform are compounded not just by the multiple roles of schools, but also by the multiple "customers" for schooling, as workshop participant Stephen Marcus explained:[29]

> To the extent that we talk in terms of the schools providing a custodial function, it seems that the customer for the school is the parent somehow, whereas if we talk about schools building community, then the customer for the school is the student somehow. . . . To theextent that we talk about preparing students for the work force, sometimes it seems as if we're talking about the good of the employer a little

[24] Workshop transcript, p. 77.

[25] Workshop transcript, p. 101.

[26] See, for example, U.S. Congress, Office of Technology Assessment, *Learning to Work*, op. cit., footnote 7.

[27] James Bosco, op. cit., footnote 16.

[28] Workshop transcript, p. 54.

[29] Workshop transcript, p. 109.

> more. . . . Who's the key customer in the school? Whom is the school there to serve?

KEY ISSUES FOR FUTURE VISIONS OF EDUCATIONAL TECHNOLOGY

The scenarios in the commissioned papers and the workshop discussion suggest that technological advances could ease the transition toward a form of teaching and learning more appropriate for the information age. The technologies that can facilitate this change are available today; however, the future scenarios assume a much more seamless infrastructure of computer, telecommunications, and connecting technologies that allows students and teachers decentralized control over their educational environment. The commissioned papers and workshop discussion focused on ways in which technology could affect such key reform issues as: changing curriculum and assessment, new teacher roles and staffing patterns, and expanded views of the learning community. They noted, however, the importance of paying careful attention to the potential "dark side of technology."

Technological Advances and Their Potential for Education

In their paper, Christopher Dede and Matt Lewis defined several categories of technologies (basic as well as more advanced) that can help with the school-to-work transition process; these are equally applicable to the general teaching and learning process:[30]

- *Presentational computer-based training and computer-assisted instruction.* These programs are predominantly tutorial or drill-and-practice and use the computer to display information and monitor student reaction.
- *Intelligent tutoring and coaching systems.* These mimic some of a teacher's cognitive abilities. These systems rely on artificial intelligence, which appears to "understand" who, what, and how it is teaching.
- *Multimedia and hypermedia programs*. Multimedia programs are designed to present information in the way that the mind assimilates it, then allow the student to interact with the material. In addition, hypermedia programs interrelate data through concept maps based on related ideas and material.
- *Computer-supported collaborative learning technologies*. Although these technologies are "not as effective as face-to-face group learning," according to Dede and Lewis, they "provide a strong surrogate for actual cooperative learning."
- *Modeling and experiential simulations.* These range from "models that mirror the simplified essence of reality to elaborate synthetic environments that place students inside alternate virtual worlds."
- *Computer-based tools as learning enablers*. According to Dede and Lewis, these tools seek to develop "distributed intelligence, in which the learner is free to focus on the concepts and skills to be acquired" because the technology assumes part of the cognitive load.
- Central to all the visions of expanded technology use for education are affordable, user-friendly, *telecommunications networks* to which all students and teachers have easy access.

The visions discussed in the futures papers depend on technologies that, by and large, are already available today (e.g., personal digital assistants, small cellular phones and integrated personal communications systems, simulation and modeling systems, collaborative computing environments, high performance work stations, and extensive use of networks) or are under development and likely to be affordable for schools in the not-too-distant future (e.g., interactive digital video and large flat-screen display technologies). However, a major difference between the present

[30] Chris Dede and Matt Lewis op. cit., footnote 6.

state of technology and the future visions is the extent and fluency of integration among various kinds of technologies. For example, in "The Big Dig" vignette, Hunter and Goldberg use a variety of technological tools that are present today; what distinguishes their vignette from the present reality is the "seamless environment of technology and information infrastructure and the fluency with which these tools are used to design and enhance learning experiences."[31] In "The Big Dig" scenario administrative and instructional technologies are integrated in ways that enable decentralized learning communities to access information (be it student health records or electronic student portfolios) where and when they need it.

Students in the Kozma and Grant scenario use a combination of technological and social supports to "scaffold" their efforts to solve new kinds of problems or address new content domains. Much like the *learning enablers* in the Dede and Lewis typography, the computer-based project tool in the Kozma and Grant paper "steps students through the planning process, asking them to define their goals, prompting them to select activities to accomplish these [goals], guiding them to resources, and structuring their assessment."[32] The tool also gives guidance and feedback on the design, development, and execution of their projects. This tool uses embedded coaching and intelligent critic capabilities that are currently being developed for advanced technologies. The tools keep plans and goals visible so students do not lose track. As students learn the process, they are expected to internalize the necessary skills. The teacher is the important social "scaffold," prompting, encouraging, and guiding the students through the process, and helping them put the learning in context.

Integrated digital and wireless telecommunication technologies are also key in the Kozma and Grant model, as their first scenario shows:[33]

> As he does every morning, Steve Early eats breakfast in front of the teleputer. While he watches a program in one window, his personal communication service relays a video message from his South African friend, Nelson, in another window. . . . This software agent presents the story as it originated in Nelson's community and then goes off to search for additional information about the train accident on GlobalNet. After Steve checks out the Net pointers, he constructs his own agent to search the local and national video news service to find video clips that run less than three minutes, sort them chronologically, and store them on the school server so he can access them later.

Access to technology in school is particularly important in light of increasing disparities in technology access outside of school. Families that can afford to purchase computers are giving their children an educational advantage, through supplementary learning activities and additional opportunities to do school work at home. Today about half of college graduates and two-thirds of those with incomes higher than $50,000 report that their children use a computer at home, compared with 17 percent of parents with a high school education or less.[34] The papers commissioned by OTA deal with this challenge by advocating increased support for technologies for all students and teachers that facilitate better links between school and home and increased parental involvement. These could include take-home computers for students, voice mail in schools and homes, dedicated school video channels and interactive video links between school and home, per-

[31] Beverly Hunter and Bruce Goldberg, op. cit., footnote 15.

[32] Robert Kozma and Wayne Grant, "Year 2005: Using Technology to Build Communities of Understanding," OTA contractor report, November 1994, NTIS No. 95-172235.

[33] Ibid.

[34] Times Mirror Center for the People and the Press, "Technology in the American Household," Washington, DC, May 24, 1994.

sonal digital assistants, and wireless modems. To be fully integrated now would require each student or family and classroom to have these technologies. Further developments of integrated computing and communication systems may obviate the need for this variety of separate components.

Changing Curriculum and Assessment

Just as the future visions are based on information technologies that already exist (even if they are not widely available in schools and homes), most are also based on changes already underway in the areas of curriculum and assessment that are tied to developing views of learning. Many states and professional organizations have developed curriculum standards in many subjects that incorporate the skills of gathering, assessing, and handling complex information and that call for instruction based on challenging tasks and complex problems grounded in the real world. These approaches often require students to work in teams on projects that cross traditional curriculum lines and to develop collaborative problem-solving approaches. As schools are attempting to provide more "authentic" instruction, many states and school districts are also developing new methods of "authentic" assessment designed to provide more in-depth demonstrations of what students know and can do than traditional standardized tests. These performance-based assessments often require the use of technological tools from simple wordprocessing to advanced multimedia.[35]

The scenario in "Year 2005: Using Technology to Build Communities of Understanding" by Kozma and Grant is based on authentic, or "project-based," learning, in which teams of students with different strengths work together on real-life issues of their choosing. By collaborating with people in the working world on specific issues, students expand their pool of resources and information. In this scenario, information technology also opens communication between schools and parents and provides new forms of documentation and products that can be used to assess student progress.

In Riel's scenario, the traditional classroom would be replaced by learning centers, which take advantage of what Riel calls the most significant technological off-shoot: a rich network of human resources. Multi-aged groups of students would work in these centers, each of which would have a specific theme, and would learn to draw on their varying strengths for success. Assessment is based on a final exhibition of student works that is attended by the school and community. Riel's fictional narrator explains the process:[36]

> We find that creating a museum exhibit that is enjoyed by the community provides more intrinsic motivation to learn. At the end of every session, the students spend time reflecting on their work as they get ready for the exhibition. They select their best work to display in the exhibition. But they also have to see how they measured up to the goals they set for themselves. The exhibition provides a time for parents and community members to see what students have accomplished. Parents can see how their child's work compares with that of children of different ages and abilities. The exhibition provides students an opportunity to teach their parents.

In "The Big Dig," Hunter and Goldberg propose another kind of model built around project-based learning, interdisciplinary studies, and group activities, many of which use technological tools. Students, educators, parents, the community, and the workforce collaborate to complete a real project and prepare exhibits about particular aspects of the project. Students in this vignette are assessed on the basis of their performance of real tasks and the students' contributions to the team. Teachers also develop assessment plans that are evaluated

[35] See, for example, U.S. Congress, Office of Technology Assessment, *Testing in American Schools: Asking the Right Questions*, OTA-SET-519 (Washington, DC: U.S. Government Printing Office, February 1991).

[36] Margaret Riel, "The Future of Teaching," OTA contractor report, November 1994, NTIS No. 95-172219.

by the outside experts who work with the students.[37]

> One of the teachers, the student assessment specialist, and one of the children form a group to review and formalize the evaluation plans. They begin by locating the assessment archives from last year's Tunnel Team exhibition. They see there were some complaints from parents last year that the evaluators had too narrow a focus and missed some important evidence of the team's creativity and communication skills. They decide to avoid that problem by having two levels of evaluation of the exhibition. They call the two levels "Quick" and "Deep." The "Quick" evaluations will be made by interviewing visitors to the exhibition who would have unpredictable kinds of backgrounds, skills, and interests but who would represent a wide range of viewpoints. The "Deep" evaluations will be made by a panel of ten people chosen from the school communities' database of teachers and expert reviewers. In creating the evaluation plan, the group makes links in the database to the individual Tunnel Team students' personal development plans, the Tunnel Team's educational goals, and the emerging exhibit component plans. From these sources, they create packets of background information and draft assessment assignments tailored for each of the ten panelists—depending on their specialty areas—learning, basic competence, communications and collaboration, personal management, information management, mathematics, engineering, inquiry methods, etc.

The students then evaluate the plan and make suggestions to ensure that it reflects all of their work. Without the technology, it would be much more difficult to collect, manipulate, and draw upon these databases of information and personal development plans.

Despite their emphasis on authentic, project-based learning experiences, Hunter and Goldberg recognize the need for other kinds of instructional experiences:[38]

> Learning is not always fun, engaging, or relentlessly faithful to the real world. It can on occasion require the repetitive performance of tasks or intellectual battle with concepts and theories that are unfamiliar, removed from "reality," even somewhat contrived. That is one reason we believe that paying attention to standards, to what students are expected to know and be able to do, is critical. Unlike past attempts at making education "relevant," contemporary preoccupation with authentic learning is grounded in the belief that there should be explicit habits of mind, competencies and core knowledge that all student are expected to master.

New Roles for Teachers and Other Staff

Extensive use of technology in the classroom typically changes teachers' roles.[39] Some futurists have even maintained that technology, by allowing students to interact directly and individually with content, makes it possible to eliminate the teacher.[40] Some teachers themselves fear that limited educational resources may be used to purchase technologies in the expectation that fewer human resources will be required. However, the OTA commissioned papers and workshop participants suggest that technology will always be just one part of the learning equation. While technological advances may make it possible for students to progress at their own pace with materials geared to their individual learning style, interests, understanding, and needs, teachers are the crucial link between students and technology.[41] Without the teacher's guidance and enthusiasm for tech-

[37] Beverly Hunter and Bruce Goldberg, op. cit., footnote 15.

[38] Ibid.

[39] U.S. Congress, Office of Technology Assessment, *Teachers and Technology*, op. cit., footnote 4.

[40] See, for example, Lewis Perelman, op. cit., footnote 20.

[41] U.S. Congress, Office of Technology Assessment, *Teachers and Technology*, op. cit., footnote 4.

nology in the classroom, technology in schools is little used and poorly used.[42] If education is to be reformed with support from technology, and if investments in technology are to pay off, OTA finds that more, rather than less, attention should be paid to teachers and their roles.

This is not to say that teachers' roles should not change. Margaret Riel gave one major reason why changes in this area are needed: "Teachers right now do about six different jobs, and there's no reason why one person has to do all six of those jobs."[43] Carrying out custodial and disciplinary tasks, collecting milk money, completing reports and paperwork often take more time than the more intellectually challenging functions that attracted people to teaching in the first place—inspiring, guiding, advising, and coaching students and imparting expertise.

Most of the experts consulted by OTA recommend significant changes in teacher roles and school staffing patterns. Some commissioned papers envision a transformation in the relationships between teacher and student, and some call for a complete reconfiguring of instructional and administrative personnel. Several commissioned papers also propose that people in the school's local community (or networked community) play a much larger role in teaching and learning by contributing their talents, knowledge, and energies to working with students and teachers. All the commissioned papers demonstrate how technology can bring local or distant experts, advisors, parents, colleagues, or friends into the school setting to provide additional teaching and learning resources.

Student-Teacher Interactions

The Kozma and Grant paper describes a new kind of interaction between teachers and students:[44]

> To fulfill our vision, teachers would need to learn not only to use the various technologies described in our scenarios, but also to design, structure, guide and assess progress in learning centered around student projects. This kind of teaching, which most teachers have rarely experienced in their own education, requires wide-ranging subject matter expertise, creativity and intellectual confidence. Teachers need to be comfortable letting their students move into domains of knowledge where the teachers themselves lack expertise; teachers need to have the intellectual confidence to be willing to model their own reasoning process when they encounter phenomena they do not understand or questions they cannot answer. Teachers must be able to roam from group to group physically and electronically, providing stimulation and coaching without dominating the group process.

Workshop participant Stephen Marcus remarked that we all have mental images of the "bad" teacher (the school marm or pedagogue) but questioned why there are no "indelible iconic images for the best kinds of education."[45] In response, Bruce Goldberg related a story about changes in student perceptions of teacher roles. In a collaborative project with Boston College, researchers at Bolt Beranek and Newman worked with a classroom over the course of a year, integrating a range of technology-based innovations. At the beginning of the year, the students had drawn pictures of their classroom that featured the teacher as the dominant figure. By the end of the project, the students drew themselves—working in groups and helping each other—as the dominant figures, although in discussion with the researchers, the students also identified the teacher as exceedingly important. "The visual image of what their life was like was not dominated by the teacher, and that's the distinction," Goldberg ex-

[42] Ibid.

[43] Workshop transcript, p. 247.

[44] Robert Kozma and Wayne Grant, op. cit., footnote 32.

[45] Workshop transcript, p. 257.

plained. "The world that they inhabited was not teacher directed, but the world that they inhabited was impossible to conceive of without the facilitating work and nurturing care of that teacher."[46]

School Staffing Structures for Instruction

Margaret Riel's model calls for major changes in school staffing structures for instructional positions. She sets forth four new levels: learning guides (para-professionals), entry-level teachers, mentor teachers, and master teachers.[47]

> Learning guides don't require a great deal of academic preparation, but they need to have good skills in working with and motivating students. . . . We wanted to arrive at a system that included those who wanted a fast entry into working with kids, but also provided a system of rewards, a career ladder that would attract talented men and women into the challenge of continually assessing and evolving the best possible educational system. . . .
>
> Entry teachers are beginning teachers. In practice, most have full credentials, but they can be hired with a provisional credential and finish their credential work while they teach. . . . The difference between a learning guide and an entry teacher is time rather than money. Entry teachers have much more time for planning and for developing ties in the professional community of educators. It is these ties that will lead to professional work and pay.
>
> The transition to *mentor teacher* will be based on the productive use of this time. . . . Mentor teacher positions are very different than traditional teaching positions—one-third of their time is free for them to take on other tasks that are related to their developing area of expertise. These might be consulting contracts, district resource positions, foundations and government grants, or work at the university in either research or education. . . .
>
> After five years of teaching as a mentor teacher, a teacher can request or be recommended for a peer review for the position of *master teacher.* . . . There is no pressure for all mentor teachers to be master teachers. . . . You have to be at the rank of master teacher to be a member of the principal or superintendent teams. But master teachers don't have to be administrators.

Riel's approach is designed to allow instructors with different motives and capabilities to work at the level of their interest and to create opportunities for teachers to advance without giving up classroom instruction.

Community Involvement

Beverly Hunter and Bruce Goldberg predict a very high degree of involvement by community members in learning and teaching. In their scenario, the concept of lifelong learning is valued by all members of the community and almost every job involves a great deal of teaching and learning. In this setting, teachers are responsible for coordinating learning both inside and outside the traditional school environment and gain greater respect from the community. Hunter and Goldberg note additional benefits that occur when teachers work with teacher colleagues and other community members:[48]

> In all these instances teaching roles are richer and more vibrant than teachers now occupy. Teachers are guides and mentors and learners, rather than mere dispensers of knowledge. Information resource facilitator, assessment specialist, technology expert, team manager and facilitator, child development expert, subject matter specialist—all these multiple roles teachers are now beginning to assume must be understood as unfolding within a team environment. Not every teacher need be an expert in each role. What is necessary, however, are changed expectations for, and conditions within, the profession of teaching.

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[46] Workshop transcript, p. 259.

[47] Margaret Riel, op. cit., footnote 36

[48] Beverly Hunter and Bruce Goldberg, op. cit., footnote 15.

How Technology Helps

While these changes in teacher roles, staffing, and pedagogy can occur without technology, they are all easier to accomplish with technology. On the most basic level, technology can help with paperwork management, thereby freeing up valuable time for teachers to work more directly with students. Technology can also facilitate other more profound transformations by opening the teacher's world to new experts and resources through telecommunications networks, by creating new opportunities for collaborative teaching, learning, and curriculum design, and by offering creative learning environments, simulations, and experiences, as shown in the scenarios.

The new roles, techniques, and teaching styles proposed in the scenarios would require that teachers receive significant training and continuing support in such areas as project-based learning, authentic assessment, community outreach, and technology integration. As OTA found in *Teachers and Technology: Making the Connection*, this kind of preparation is far from the norm in most teacher education programs and is seldom provided as a part of continuing professional development for those already in the classroom.[49]

An Expanded View of the Learning Community

An expanded concept of a learning community, with stronger links among school, home, workplace, and neighborhood, is central to several of the future visions discussed in the papers and the workshop. In these future visions, technology provides schools with access to many more resources beyond the constraints of the traditional "closed" classroom, to the point that, as workshop participant Ted Kahn suggested, "the notion of school as a *building* drops away. . .the school becomes a consortium of available resources, people, teachers, and kids who can provide value to others."[50]

In their paper, Kozma and Grant suggest this definition of community:[51]

> A community is a collection of individuals who are bonded together either by geography or by common purpose, shared values and expectations, and a web of meaningful relationships. In the communities that we envision in this paper—what we call "communities of understanding"—education is the common purpose, learning is highly valued, and a high level of academic achievement is expected of students and their schools. . . . Today, schools, homes, and workplaces function separately—connected by geography and circumstances but infrequently by common purpose and collaborative action. But in our vision of communities of understanding, digital technologies are used to interweave schools, homes, workplaces, libraries, museums, and social services to re-integrate education into the fabric of the community.

Margaret Riel, on the other hand, reinforced the importance of both local and virtual communities: "I see community in two ways, both the geographic community and the virtual communities that we can create on-line. In the virtual communities, we need to bring together the educational community, find ways for them to talk more with one another and share what they're doing."[52] In Riel's scenario, the local community plays a significant role in education, connecting the school to the working world and supporting the teachers through a school-community council. The global community offers additional resources, accessible through electronic and telecommunications technology.

[49] U.S. Congress, Office of Technology Assessment, *Teachers and Technology*, op. cit., footnote 4, pp. 165-206.

[50] Workshop transcript, p. 224.

[51] Robert Kozma and Wayne Grant, op. cit., footnote 32.

[52] Workshop transcript, p. 323.

One of Riel's fictional narrators explains how schools interact with both kinds of communities:[53]

> Many of the ideas for our plan have come from our work on-line with schools around the world. Working with distant teachers has resulted in many new ideas that I don't think we would have had without electronic connections. . . . By making it possible for our teachers to work with the larger educational community, they have developed expertise in national and international arenas which enriches their teaching and brings many rewards to the whole district.
>
> [In the local community] our Community Council is a combination of our former PTA and school site council. One of the things we do as part of the council is to encourage all community members to come to our exhibitions—even if they don't have children. We want them to see the school as *their* school. Everyone needs to be involved, not just parents.

The model presented by Hunter and Goldberg in "The Big Dig" emphasizes how technology can bring together learning, work, family, and neighborhood in ways that are far from typical in schools today:[54]

> Ten years ago [in 1995], teachers and students spent all their time in "school buildings," sealed away from the vital life of learning and information their communities offered. On the other hand, the majority of adults were not a part of the formal educational system and thus had little opportunity to participate in organized learning activities. Advances in communications technology had helped break down some of the walls.
>
> [As an outgrowth of several federal and state initiatives] the Boston Metropolitan Education Region (BMER) was funded by a combination of these federal, state, industry, and local funds. . . . As its first pilot project, BMER issued a Request for Proposal to students, teachers, and community members inviting them to design a nine-week project that would engage all the participants in collaborative projects without regard to the political boundaries of their school districts.

Participants and contractors suggested that technology is the key to making schools more inclusive and more connected with the home, the workplace, and the local or global learning community. Otherwise, the scheduling, security, transportation, and other realities make the concept of an interconnected community of learning seem "totally unworkable."[55] "The Big Dig" continues:[56]

> [After a few years of juggling schedules to continue supporting both individual schools and the new collaborative projects] the very contentious issue of scheduling had come to a head in the BMER. It had been extremely frustrating to try to conduct city-wide learning activities that were constantly competing with the rigid class schedules of the separate schools. The separate schools were also at a point of crisis about scheduling because they were also attempting to conduct interdisciplinary project-based learning activities that could not function in 45-minute class periods. . . . [T]hey realized that the technology they were using could free them from some of the time constraints of their school traditions.

Telecommunications technology makes it possible to "knock down walls" between schools and the community. Group projects can involve people from very different areas, even different countries, and teachers and students can interact on more equal footing with others in the outside

[53] Margaret Riel, op. cit., footnote 36.

[54] Beverly Hunter and Wayne Goldberg, op. cit., footnote 15.

[55] Robert Kozma, workshop transcript, p. 82.

[56] Beverly Hunter and Bruce Goldberg, op. cit., footnote 15.

world. In the GLOBE program[57] and similar telecommunications projects, students around the world become researchers, collecting, sharing, and analyzing data on meaningful topics identified by international scientists, who then use the data as part of a growing database on scientific topics such as worldwide ecological change. For example, one group is analyzing the effects of ozone layer depletion on various species of pine trees around the world. When the school and the community beyond its walls, whether local or global, become partners in the advancement of knowledge and understanding of issues of common concern, the work of each of the partners within the learning community is valued by all members.

Similarly, in the vision of Kozma and Grant, technology links students not just to their local community, but to the global community. In their scenario, a hazardous railroad fuel spill in South Africa prompts students in a California school to begin a project about how to make tank cars safer. The project has immediacy for the students because they can communicate with people directly affected by the spill.[58]

> The students decide to make an interactive multimedia report as their final product. "You need to think about your audience for the report," comments Mr. Shepherd, their language arts teacher, "and what they would want to know about your topic."
>
> The students decide they will interview Steve's South African friend Nelson [a "telecommunications-pal"] and ask his schoolmates to collaborate with them by gathering video images and other local information about the train accident that can be integrated with the information they create. They will also talk to community members in the McAuliffe neighborhood and see whether there have been any fuel spills in the area during the past year. Finally, they will come up with some suggestions for how to stop fuel spills. They will store their report on the community video server and make it available throughout the community-access cable channel and send it to Nelson and his South African classmates. The report will conclude by taking viewers to the Environmental Chat Room on the GlobalNet, where they can talk to scientists, environmentalists, and others about the problem and potential solutions.

A sense of community, which is fostered and maintained by technology, drives the interest of the students in this scenario and pushes them to investigate difficult subjects. Technology makes the rest of the world newly accessible and newly relevant to them.

Is There A "Down Side" to Technology?

Not all contractors and workshop participants were fully optimistic about the impact of technological advancements on education. The "dark side of technology" could include several areas:[59]

- Downsizing of the teaching force as staffing patterns are altered. (Many workshop participants felt that major changes in staffing, such as those proposed by Riel in her paper, would be challenged by teachers and administrators who faced possible job loss.)
- Greater inequalities in knowledge and skills among different groups of students due to differential access to technological resources. Will adding more technology to the most technologically advanced schools exacerbate discrepancies between the technology "haves" and "have nots," creating inequalities in access to information between students who attend the "have not" schools and students who attend the "have" schools?
- Concerns about whether learning through technology is always the best way for students

[57] Global Learning and Observations to Benefit the Environment (GLOBE), 744 Jackson Place, NW, Washington, DC 20503. For more information contact info@globe.gov.

[58] Robert Kozma and Wayne Grant, op. cit., footnote 32.

[59] Workshop transcript, p. 150.

to learn. Will an over-emphasis on technology mean that students who would benefit from direct, traditional instruction get lost in the shuffle of changing approaches to teaching and learning?
- Potential harmful influences from opening the sheltered class to the outside world. Telecommunications networks could give students easier access to questionable or dangerous elements, such as pornography on the Internet.

Proponents of rapid technology integration counter by saying that the education reformers share this concern to avoid the "down sides" of technology. One participant noted: "It's largely because we understand the dark side of technology that we feel such a responsibility to ensure the beneficial applications and to try to minimize the dark side."[60]

IS THERE A FEDERAL ROLE?

The viability of many of the future scenarios will depend largely on value choices and economic investment decisions made by Congress, state and local policymakers, and the American public. Realizing the most promising of these future visions will entail a greater commitment to education—in both funding and energy—than the United States is making today. However, advancements in educational technology and developments in educational reforms are taking place at the same time the nation is undergoing a very critical debate about government and other institutional responsibilities in education. The next five to 10 years are likely to see major changes in federal, state, and local roles in education. Congress is considering decisions that will greatly affect the amount of federal funding for education, the number and type of federal education programs, and the nature of federal education requirements. Congress is also making decisions in the area of telecommunications infrastructure policy and regulation that will have an enormous impact on whether schools have access to technology and a defined place in the National Information Infrastructure.

The current movement in education appears headed toward decreased federal funding, fewer federal programs and requirements, and shifts of education responsibilities from the federal to the state and local levels. Together these developments suggest the need for policy discussions that examine the federal role in conjunction with state, local, and private sector roles and that look at creative options for providing financing and leadership from a variety of sources, not just the federal level. State and local policies for education, telecommunications regulations, and the policies of local public utilities commissions are also critical.

Workshop participants devoted much discussion to the roles the federal government might play in advancing appropriate uses of technology to support learning. Many of the options mentioned were consistent with the realities of limited federal funding and fewer requirements on local schools. The options suggested include supporting and disseminating models of effective practice, providing research and development activities, assuring equity, and encouraging new funding sources. These federal options are not novel. What was unique was the consideration given to how technology itself might improve traditional federal models of evaluation, dissemination, funding, and equity.

■ Support for Models of Effective Practice

One clear federal role suggested by workshop participants was that of evaluating, promoting, and disseminating the innovative and promising activities already being undertaken by local centers of technology excellence. The federal government could support and encourage the "scaling up" of these kinds of innovative learning communities. "Innovation is local," said Beverly Hunter. "We have to be locally opportunistic about the nature of innovation. Because each locality has different

[60] Beverly Hunter, workshop transcript, p. 156.

resources and different expertise. . .[consider] the possibilities of getting synergy from sharing across localities both know-how and resources."[61]

Some participants suggested that the federal government establish mechanisms that encourage creation and sharing of local processes in support of education—empowerment zones—that provide incentives for business to develop stronger relationships with schools, hospitals, or others; perhaps relationships in which shared investments in telecommunications networks benefit all users.

Research and Development Activities

Consistent with the old saying about giving a hungry man a rod and teaching him to fish, the federal government might subsidize the educational equivalent of the "better fishing rod" or "special worms"—development support for technological tools that help make localized activities more effective, such as software tools for better network access, curriculum materials using the capabilities of newer technologies, pornography firewalls, or new teaching tools such as those used in science experiments, mathematical reasoning, or design activities.

Promoting Equity

Participants also expressed concern that issues of equity remain central to the federal vision. While most welcomed the developments that are bringing powerful learning technologies into the home, many pointed out the possibility of even greater imbalances in learning opportunities among various groups, including parents who can afford a curriculum-based multimedia learning system for their children and those who cannot. How can imbalances be corrected between the community that commits an $8 million local bond to wiring the schools and the one next door that does not?

Funding Sources

Participants in OTA's workshop debated where funding might come from that could provide all children with equal access to the best available learning and communication tools. One suggestion was that the federal government provide significant start-up support for infrastructure development, as was done with the interstate highway system. Another suggestion was to encourage private sector investment in schools through innovative tax policy. As Nancy Hechinger suggested, "What if you say to corporations that you could [choose to] not pay 10 percent of your corporate tax if it goes to education? Or let every corporation in the community elect, like the federal income tax check off for Presidential elections, to allow a portion of their taxes to go directly to a school?"[62]

Others suggested that schools pay for reform and technology investments the way that businesses have: by reducing labor costs through eliminating teaching or administrative positions, reshuffling staff, or automating certain duties with technology, and investing the savings in technology. This option is similar to the funding mechanisms proposed in Margaret Riel's scenario, which eliminates some administrative positions in favor of collaborative teacher leadership and creates a new salary scale for the four levels of instructional positions. Her scenario projected relatively low yearly costs for reform despite substantial technology investments.

The Hunter and Goldberg scenario also assumes some cuts in personnel costs through workforce restructuring. The main funding for "The Big Dig" project, however, is envisioned to come from a cooperative venture of local, state, and federal governments and private industry, working through a hypothetical "Boston Metropolitan Educational Region." Hunter and Goldberg sug-

[61] Workshop transcript, p. 280.

[62] Workshop transcript, p. 295.

gest that entities such as the BMER could be financed through a combination of such means as:

- money drawn from a "lifelong learning account," created for each citizen at birth and expended throughout an individual's life for a variety of learning activities;
- revenues earned by non-profit educational corporations from the creation and sale of socially useful products or services and from leasing space during off-hours;
- income from "entrepreneurial education zone" activities, in which teachers and students produce knowledge with economic value, such as selling information on Web pages, working with local businesses, or generating ideas, products, and information of value to communities; and
- support from the biotechnology, finance, software, and other industries for learning centers that train people and provide school-to-work transition services.

In addition, the Hunter and Goldberg vignettes presume innovative use of space and facilities, including:

- satellite learning centers, such as the public educational facilities that businesses in Dade County, Florida and elsewhere have built on their premises;
- shared use of public and private facilities, such as municipal buildings, libraries, and corporate job retraining centers;
- neglected buildings that could be renovated for educational use by public-private partnerships, with incentives from federal enterprise zone legislation; and
- new and renovated schools designed with advice on best design practices from community experts, foundations, or federally disseminated research sources.

Hunter and Goldberg also suggest that research and development about technology-based learning and cognition could be supported by requiring a percentage of funding in support of school reform to be devoted to conducting and disseminating research on the learning outcomes of alternative approaches to teaching and curriculum, including the integration of technology into these activities.

WILL PROMISING VISIONS BECOME A REALITY?

Can the technological changes presented in the most promising of these visions become reality? Workshop participants were divided on how much change can be expected in schooling. They concurred that change usually comes slowly to schools but they agreed that when required, schools can and do change.

As one analyst wrote, "Like battleships, the schools are large, powerful, cumbersome institutions, difficult to maneuver" and slow to change direction.[63] Nevertheless, schools have changed when there is strong pressure or good reason; schools today are the result of several generations of reform in such areas as desegregation, curricular emphasis, and special education. Reform based on technology presents many unique challenges, however. Past reforms were not dependent upon instructional technologies, and it was not until the 1980s that school reformers began to seize on electronic technologies as a way of "unfreezing the perceived inefficiencies and rigidities of American schooling."[64]

In his early work, Alvin Toffler believed the educational system would be a leader in embracing technology, incorporating it long before industry and private organizations. He believed that schools by nature were more likely to embrace change, citing a "venturesome spirit which stands

[63] Patricia Graham, op. cit., footnote 22, p. 4.

[64] Larry Cuban, "Public School Teachers Using Machines in the Next Decade," OTA contractor report, November 1994, NTIS No. 95-172243.

in total contrast to the security-minded orthodoxy and conformity associated with the organization."[65] This optimism about school change was misplaced; 25 years after this prediction, business and industry are technologically far ahead of the schools, and schools are struggling to keep up despite the benefits that technology offers them.

Workshop participants and contractors cautioned against easy comparisons with business. "Schools differ substantially from other institutions in their workplace characteristics, in the nature of teaching children, and in public expectations . . . [school structures are] profoundly difficult to change."[66] Others noted the fundamental difference between business, in which the goal is to "do" and the bottom line is profit, and schools, in which the goal is to "be" and the bottom lines are many (e.g., meeting the social mandate). They suggested that schools find their own models for restructuring and not take their guidance from business.

Larry Cuban explains his view of why the integration of technology will not occur at the rapid pace many envision:[67]

> Technophiles . . . often minimize the power of social beliefs that have endured for centuries and perform important functions in society. Beliefs that teaching is telling, learning is listening, knowledge is subject matter taught by teachers and books, and the teacher-student relationship is crucial to any learning dominate much popular and practitioner thinking. Most parents expect their schools to reflect those centuries-old beliefs.

Larry Cuban's paper offers three scenarios of possible educational change involving technology: the technophile's vision in which electronic schools of the future become widespread rather quickly; the preservationist's scenario in which schools maintain their current features but add technology as an important yet peripheral component; and the cautious optimist's scenario, in which schools move slowly toward fundamental changes in teaching and schooling using technologies. He argues that the time and rate of technology-based school reform may vary by grade and kind of school. At the high school level, change may be relatively slow, more in keeping with the preservationist's model, in which "policy makers and administrators put computers and telecommunication technologies into school largely to improve productivity but not to alter substantially existing ways of organizing a school for instruction."[68] At the elementary school level, the cautious optimist's model may be more likely.

Cuban bases these different predictions on what he sees as fundamental differences between elementary schools and secondary schools:[69]

> Public elementary and secondary schools differ markedly in the complexity of content students face in classrooms, teachers' formal training, allocation of time to instruction, and external arrangements imposed upon both levels from other institutions. . . . The point that I wish to make is that how the age-graded school is organized for instruction at the two levels determines to a large degree which scenario will most likely occur. The preservationist's scenario is most likely in high schools where academic subjects reign, teachers' training was in disciplinary content, and the number of classes and students teachers teach remains high. The cautious optimist's scenario is more likely to occur in elementary schools where organizational differences make shifts in practice possible and where hybrids of teacher-centered and student-centered instruction have, indeed, evolved slowly over the last century.

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65 Alvin Toffler, *Future Shock,* op. cit., footnote 11, p. 148.

66 Larry Cuban, op. cit., footnote 64.

67 Ibid.

68 Ibid.

69 Ibid.

The problem, suggested some workshop participants, is not so much in getting schools to adopt something new, but rather in getting them to give up the old, thereby creating time, resources, and enthusiasm for the new. Far too often, technology is an add-on rather than an "instead of." Similarly, in order for teachers to take on new roles, they must be allowed to drop some of the old; otherwise, they end up with an unbearable load of responsibilities on their shoulders.

The papers by Bosco, Riel, Kozma and Grant, and Hunter and Goldberg anticipate faster change and more radical revisions in schooling than does Cuban's. As described (box 1), the future is difficult to predict, and more promising futures do not just happen.

CHOOSING A FUTURE

The American educational system is at a crossroads as regards both technology and broader education reform. More and more people inside and outside the schools are calling for deep and fundamental changes in school organization, instruction, content, and processes. This climate creates an opportunity for innovation that has perhaps not been present for over a century. Technological advances provide additional impetus for reform and also offer new tools for implementing their reform.

Whether the nation will have the vision and commitment needed to make courageous choices about education reform remains to be seen. On one hand, the cumulative evidence over the past 25 years suggests that schools are more resistant to change and have less of the "venturesome spirit" that Alvin Toffler saw in them in 1970.[70] And on a national level, there is no clear agreement about the kinds of reforms needed in education, the level of commitment required to achieve meaningful reform, or the role of technology in education reform. On the one hand, there are those who suggest what is needed are traditional approaches: a return to basics and greater investment in staff and textbooks rather than investments in new information technologies. On the other hand, many communities around the nation are demonstrating how technology and reform can come together and produce effective results.[71] The stated commitment of the Administration to put all the nation's schools on the National Information Infrastructure and the expressed interest of congressional leaders in increasing the use of technologies in education are promising steps, but whether these goals will be fulfilled remains to be seen. There is no guarantee that this vision will not become another casualty of shifting culture and political winds.

Perhaps the real factor that will determine the future of technology in education reform will be the extent of the national commitment to a high level of learning for all students. As one leading educator observed, providing only data, even on an information superhighway, may not be enough. He distinguished among data, information (data with a context), knowledge (information with usefulness), and wisdom (knowledge informed by sensibility and experience).[72] How do we Americans define knowledge, let alone wisdom? How do we recognize it? What kinds of learning do we really want for our children? How do colleges, universities, and employers characterize and reward different levels of learning? In 1948 Vannevar Bush and his contemporaries were concerned with the creation of information, and in that con-

[70] Alvin Toffler, *Future Shock*, op. cit., footnote 11.

[71] For a brief review of the state of the art in technology effectiveness research, see U.S. Congress, Office of Technology Assessment, *Teachers and Technology*, op. cit., footnote 4.

[72] Stephen Marcus, panel discussion on, "Hypermedia and Lifelong Learning. . .50 Years After Vannevar Bush. . . And Beyond," National Educational Computing Conference, 1995.

BOX 1: Predicting the Impact of Technology

Technological advances always invite speculation about their impact on the future Often projections about technology are wildly optimistic or utopian, and just as often they vastly underestimate the impact of a technology An example of the tendency toward optimism is Thomas Edison's claim that the motion picture would result in the elimination of textbooks from schools. [1] And a famous example of the tendency toward underplaying is the reaction of the chief engineer of the British Post Off Ice who, upon hearing news of the invention of the telephone, reportedly told his colleagues, "The Americans have need of the telephone, but we do not We have plenty of messenger boys "[2] More recently, even presidents of major computer companies have failed to foresee the huge demand for computers Shortly after World War II, Thomas J Watson, Sr., founder of IBM, "predicted that five machines would make up the world market for computers "[3] And in 1970, Kenneth Olsen, founder of Digital Equipment, stated he saw "no reason for any individual to have a computer in their home "

Other predictions have been close to the mark; in 1945, Vannevar Bush predicted the invention of a device he called the "memex, " in which "an individual stores all his books, records and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility"[4]—not far removed from today's computers with CD-ROMs and Internet connections

Similarly, past predictions about the future of education have also tended toward the utopian or the dire, and have generally overestimated how quickly schools would change Futurists such as George Leonard in his 1968 book *Education and Ecstasy*[5] share a view that schools and technologies will advance together Many of today's education futurists, including most of the OTA contractors and workshop participants, also suggest that the impact of technology on education could be profound For example, in his paper "Schooling and Learning in an Information Society, " James Bosco describes what he sees as the climate for change set in place by Information technology: [6]

> There is little reason to believe that information technology will bring either heaven or hell to earth, but It is clear that information technology is causing profound changes in how we live, work, play, and learn Many will continue to debate whether Information technology is making our lives better or worse, but there is little argument that information technology is making our lives very different than they were before this technology was Invented
>
> The changes caused by Information technology in what and how children, youth, and adults learn are not something we await in the future, we are in the midst of these changes Information technology is transforming the amount and nature of the Information content of civilization as well as the processes whereby this Information is acquired The modest changes in the nature and conduct of schooling in recent decades stand amidst monumental changes in how, when, where and what learning occurs in our society As Information technology-based learning opportunities become increasingly ubiquitous and efficacious, schooling, teaching, and learning will take on a new character and a new balance between school and non-school learning will be established

[1] Larry Cuban, *Teachers and Machines The Classroom Use of Technology Since 1920 (New* York, NY: Teachers College Press. 1986), p. 9.

[2] A.C. Clarke, *How the World Was Won* (New York, NY: Bantam Books, 1992), p. 224, as cited in J. Bosco, p. 1.

[3] D. Leebaert, "Later Than We Think: How the Future Has Arrived," *Technology 2001 The Future of Computing and Communications,* D. Leebaert (ed.) (Cambridge, MA: MIT Press, 1991), cited in Bosco, p. 2.

[4] Vannevar Bush, "As We May Think, " *Life,* Sept. 10, 1945.

[5] George Leonard, op. cit., footnote 8.

[6] James Bosco, op. cit., footnote 33, pp. 2-3.

text, machines are capable of success. But the ultimate goal—instilling wisdom—is a much harder one to meet.

These papers and workshop created a basis for discussion. The issues they raise for the future for America's children are too important to ignore.

Appendix A
Schooling and Learning in an Information Society

A

"We have now reached the stage when virtually anything we want to do in the field of communications is possible: the constraints are no longer technical, but economic, legal, or political." Arthur C. Clarke (3)

Whether one considers it a curse or a blessing to be born in "interesting" times, such is the plight or good fortune of the current generation. Events and inventions of the past several years strain credulity even for those accustomed to seeing the unlikely occur. There is little doubt that the years at the later part of the 20th century will provide a rich subject for historians as they explain to future generations the remarkable events of today. Those of us living amid this period of monumental change are faced with the difficult task of pulling back to gain perspective to see what is so close to us.

No developments among those of the past several decades are of greater consequence than those pertaining to information and communications technology. We have come to the point where indeed as Arthur Clarke says, "anything we want to do in the field of communications is possible." This audacious statement is correct even when we broaden the scope to include information/computer technology; for indeed, the line between communications and information technologies is sufficiently blurred so that it is impossible to know where one ends and the other begins.

The relevance for students and teachers of a technology that is used by scientists, technicians, business people, public officials, and others as the dominant means to create, store, and distribute information is obvious. As computer applications for personal productivity become increasingly powerful and prevalent, and as networks become the "places" where scientific, technical, and cultural information is stored, there is little reason to wonder if

by

James Bosco

Western Michigan University

such technology belongs in schools. Schools, no less than other agencies, and more than many, need to take advantage of information technology. The essence of the issue for schools is this: If anything is possible, what should we make probable in schools? What should be done to make the immense capability of information technology a means for improving the lives of our children and for enabling them to live productive and satisfying lives in an increasingly complex and changing world?

Every new technology brings with it speculation about the impact of the technology on the future. Looking back, it is not difficult to find those who look silly because they badly underestimated the significance of a major technological advance. Arthur Clarke tells of the reaction of the chief engineer of the British Post Office upon hearing of the news of Alexander Graham Bell's invention. He told his colleagues, "The Americans have need of the telephone—but we do not. We have plenty of messenger boys . . . " (3). This British Postal Official made the mistake of thinking that the telephone would fit—or fail to fit—into the world as he knew it. He did not allow the possibility that the telephone would generate other developments which, in a sense, would remake the world so as to create a place for itself. Similarly the impact of computer technology has been misunderstood even by some who we might think would have been unlikely to do so. Shortly after World War II, Thomas J. Watson Sr. predicted that five machines would make up the world market for computers and, as recently as 1970, Kenneth Olsen, the founder of Digital Equipment Company, was quoted as saying that he saw "no reason for any individual to have a computer in their home"(17). "Solemn prophesy," J. B. Priestly is reported to have said, "is obviously a futile proceeding, except insofar as it makes our descendants laugh" (16).

Speculation about the impact of technology often takes a utopian tone; the technology is seen as the means to achieve whatever lofty goals the proponent espouses. Ralph Waldo Emerson, who believed that America was destined to be a pastoral republic, hailed the advent of the steam locomotive. Railroad travel, he believed, would disperse the population to rural communities. As a result of the invention of the steam locomotive, Emerson believed that the time was coming when, in his words, "the whole land is a garden and the people have grown up in the bowers of a paradise" (14). Emerson's prediction reads no more quaint or mistaken than the statements from computer proponents which abounded in the early 1980s about a "computer revolution" which would transform the schools and turn them into their own realization of an educational paradise by the end of that decade.

New technologies typically also generate a body of apocalyptic commentary. While Emerson greeted railroad technology as a means for improving the human condition, his contemporary Herman Melville was among those who feared that the machines emerging during this time would undermine the human condition. The theme of technology as a nefarious force which reduces human control and denigrates human values is longstanding. This has been the case with computers and information technology. Many persons have expressed the fear that computers would depersonalize schools as children sat before a screen without any human contact from teacher or peers.

The record of past technologies suggests that the consequences of technology are seldom, if ever, so consistent or unambiguous to warrant either the utopian or apocalyptic characterization. There is little reason to believe that information technology will bring either heaven or hell to earth; but it is clear that information technology is causing profound changes in how we live, work, play, and learn. Many will continue to debate whether information technology is making our lives better or worse, but there is little argument that information technology is making our lives very different from what they were before this technology was invented.

The changes caused by information technology in what and how children, youth, and adults learn are not something we await in the future; we are in the midst of these changes. Information technology is transforming the amount and nature of the informational content of civilization as well as the processes whereby this information is acquired. The modest changes in the nature and conduct of schooling in recent decades stand amidst monumental changes in how, when, where, and what learning occurs in our society. As information technology-based learning opportunities become increasingly ubiquitous and efficacious, schooling, teaching, and learning will take on a new character and the establishment of a new balance between school and nonschool learning will be established.

CURRENT CONDITIONS IN SCHOOLS

In the past couple of decades, the plight of United States public schools has been documented in many books and articles; thus, a detailed account is not necessary here. A brief recapitulation of key aspects of the current status of schools will provide the context for the ensuing discussion.

- **Widespread dissatisfaction.** With the publication of *A Nation at Risk,* concerns which had been building in the preceding years about the American public schools coalesced and achieved prominence. Concerns about declining test scores, the fitness of American young people to provide the skills required by American business and industry, and the prevalence of drugs and violence in American public schools became a major issue in federal and state political campaigns, as well as a popular story in the print and broadcast media.
- **Federal, state, and local reform efforts.** Dissatisfaction about the status of the schools led to the creation of America 2000 which was the federal response to the need for a national reform of American schools. Many state legislatures enacted reform legislation of various types, such as charter schools, mandated school reform plans from local districts, lengthening of the school day or the school year, etc. At the local level, thousands of reform projects were initiated. While most of these were modest in intent and scope, a number of more extensive efforts were launched.
- **Privatization.** A number of school districts entered into contracts with private corporations to provide services previously provided by public employees, such as custodial work, transportation, special education, etc. The most extensive use of "contracting out" by a public school was announced in October 1994, when Minneapolis-based Education Alternatives, Inc. entered into a contract with the Hartford Public School District to run its schools. The Edison Project led by Frank Whittle was an even more ambitious plan for school privatization. This project, which began as an effort to develop a nationwide network of schools under the aegis of a private, for-profit corporation, more recently has entered into negotiations with school districts to develop contracts to provide instructional programs in a manner similar to Education Alternatives, Inc. By the later part of 1944, fiscal distress in the Whittle empire made the future of the Edison project tenuous.
- **Constraints.** Even though school reform laws have been enacted in states throughout the nation, state law and policy is frequently a barrier to change. Collective bargaining agreements also offer a substantial obstacle to change. College entrance requirements form yet another barrier since entrance requirements play a substantial role in setting curriculum requirements for high schools. Parents who may support curriculum changes at the high school become less supportive if it appears that the changes will compromise their child's college entrance. The climate and morale of schools provides yet another barrier. In some cases teachers and administrators may resist change, but it is not uncommon to find instances wherein teachers supportive of the need for change "do themselves in" with a self-fulfilling prophesy of failure based on past experiences.
- **Technology integration.** Much of the discussion about schools and information technology in the 1980s and 1990s has focused on how the technology could be integrated with the existing fabric of life in schools. From a political, as well as from a business point of view, this may be a plausible stance. If the task is to sell computers to schools or to persuade teachers to use them, then it is sensible to try to make them fit

into schools as they are now. If, however, the task is to use information technology to renovate schools, then the disintegrative aspect of the technology becomes the focus. Information technology becomes a means for disrupting existing practices and for creating a new way of schooling rather than becoming an accouterment to the existing practices.

PURPOSE AND FOCUS

This paper is written for the United States Congress, Office of Technology Assessment study entitled "Teachers and Technology." The purpose of the paper is to analyze the opportunities, prospects, problems, and barriers for technological change and its impact on K-12 schooling in the next five to 10 years. The question which serves as the focal point of this paper is: What are the implications of information technology for schools and learning in American society?

The use of the two terms "schooling" and "learning" in the title of this paper is not a redundancy. The pivotal point in this paper is the distinction between schooling and learning. Learning refers to the fundamental human process by which individuals acquire the knowledge, skills, attitudes, and perspectives which enable them to function in society. Functionality requires a range of complex skills such as language, understanding of rules of conduct and social interaction, life skills such as required by the specifics of the environment wherein the individual lives, and an array of cognitive skills such as reading, writing, etc. Schooling refers to the institution which, for the past century and a half in the United States, has been expected to accomplish the preponderance of learning outcomes for children and youth. Schools operate within a framework of well-established, and until recently, well-accepted policies, practices, and conventions. The educational impact of information technology is not confined to schools, and it is only when the broader implications of information technology for where and how learning takes place in society beyond the boundaries of the school are considered that we can understand what can and should done in schools.

Information technology, which has caused a transformation in so much of how life is lived in the waning days of the 20th century, has not bypassed how learning occurs in American society and will affect schooling, even though such has not occurred to any appreciable extent at present. Many persons have called for schools to be proactive with regard to the implications of information technology for school practices. There is less reason to be concerned about the lack of proactiveness in schools on this matter than their lack of reactivity. Teachers, administrators, and policymakers need to understand what is happening all around them and react to cause the changes to make schooling harmonious with a new way of living, working, playing, and learning.

In order to understand the full significance of the impact of information technology on human life and learning in particular, it is necessary to step back and take a quick journey through a half million years of human existence.

THE THREE GREAT CODES AND THE CREATION OF HUMAN CULTURE

Over the span of human history, from the dawn of time to the present moment, there have been three great inventions which have shaped the development of human culture. Each of these inventions has been an innovation in communication, and in each instance a new chapter was begun in the story of civilization. The current generation is in the midst of the invention of one of these codes and is witness to changes of a magnitude which are rare; only a handful of generations among the thousands who have walked on earth have ever experienced events such as these.

In the beginning was the thought. Certainly, there could not have been the word had there not been the thought. Human beings have an inner life of the mind. They think, and it is the ability of *homo sapiens* to be conscious of what he or she is thinking about which is the basis for the creation of human culture. As a human being we can "look" into our own mind and "reflect" on our thoughts. We see the faces of those whom we encounter, but we are not privy to their inner life unless they choose to tell us about it. Nevertheless, we know that their minds, like ours, are spinning a tapestry woven of thoughts and feelings. Writers such as Proust tried to present a representation of "stream of consciousness" in their work, but it is terribly difficult to provide a completely faithful representation of human consciousness because of the dynamic and amorphous nature of consciousness.

Human beings had consciousness long before they had any particularly effective language system to tell others about it unless a scream of pain, a sigh of ecstasy, or a grunt of approbation is to be considered a language system. The initial step in the story of the creation of human culture was the invention of the first great code which was used to put what was in the mind into a form which enabled the transmission of the inner world of the mind to others. Sounds produced in the larynx were used to represent cognition, and as language developed, increasing richness and subtlety of expression was possible.

The invention of speech changed the human condition. Even with the fullest power of our imagination, it is difficult to get a good sense of how different life must have been when human beings existed together without the ability to talk to one another. With speech it became possible not only for one person to see another's face, but also to hear what was in their mind. Unlike the changes resulting from information technology which are occurring in the world at present, changes which are propelling us from one era to a new one in the span of a generation, the development of speech occurred over thousands of years. Thus, the changes in how the increasing sophistication of speech affected the nature of human existence were so gradual as to be scarcely noticed.

Speech provided a new dimension to human interaction. Speech made thought a social commodity. With speech it became possible to make public and to store human cognition. The knowledge of individuals could be accumulated and the accumulated knowledge of the society was stored in the brains of the elders. By memorizing the accumulated knowledge of the society and by passing it to successive generations by word of mouth, the products of human minds achieved a durability beyond the life span of the humans "who thought them up." Just as a person could leave the product of their hands such as a bowl or an ax to their progeny, speech now enabled them to leave behind the products of their mind—their stories, their truths, their ideas.

Speech was responsible for the first and, in a sense, the most important information revolution. The spoken word provided a means for humans to put structure to thought and to transmit it to others. By so doing, information was created. Speech made it possible for one person to tell something to another person, i.e., for one person to inform another. Information may be significant or trivial, true or false, valuable or worthless, but in each case the transference of information requires a shared coding system which makes the information intelligible to those who know the code. The nature of the coding system and the second order consequences which result from it create distinct conventions, processes, and beliefs pertaining to the accumulated information of the culture.

The second great step occurred with the development of a code which made use of graphic symbols to record speech. The earliest known use of graphics was the cave drawings of the Upper Paleolithic period, c. 30,000 - 10,000 BC, in southwestern France. The earliest use of writing involved the use of written symbols for numerical information such as calendars, inventories of property, etc. These cave drawings were probably not a primitive form of writing but were representational of important aspects of the life of early humans in a way similar to primitive music and dance. The first use of graphic symbols as a means to code speech occurred around 3500 BC after about 500,000 years of human experience with an oral tradition (27). The literate tradition was born.

Several millennia later, the advent of printing providing a means for information to become more popularized because of the favorable economics of movable type as contrasted to manuscript production. Early printing simply automated manuscript production. The form of the modern book did not fully evolve until about a century after the invention of printing. A series of inventive and generally unknown printers created the form of the modern book with a title, author, and publication information page, a table of contents, an index, and page numbers. An additional line of developments created the modern library, which initially was private but later (largely stimulated by private philanthropy) became public. As more and more books become available, it became necessary to devise ways to retrieve information. Earlier such was not necessary since a literate person would know of all of the books for which they had use. The information explosion caused by the invention of printing necessitated the development of systems for cataloging books, such as the Dewey Decimal System. The economics of printing along with the invention of new processes for the manufacturing of paper were sufficiently favorable so as to make printed material—books, newspapers, magazines, encyclopedias—available to everyone who could read.

For most of the era of literacy, written information was available to only a small number of people. It is only in the past few centuries that people other than an educated elite have access to written material. This fact is generally known. Less well recognized is the fact that until the development of cheap papermaking processes in the 14th century (a development stimulated by the invention of the printing press) pictures were a scarce commodity. Artists were available to the nobility to depict historical scenes as well as portraits. For the ordinary people, pictures in the stained glass windows of the great cathedrals of Europe were used to provide information about the life of Christ and the saints. Pictures, like words, are means of storing and distributing information, but their value and their use as a communication or learning resource has often been minimized. Cheap paper opened an iconic as well as a literate domain to a greater number of people, but reading pictures requires no training and the fact that pictures are so universally accessible may explain why the value of pictures as an information source has been underestimated.

While both the oral and literate traditions are means of constructing and storing the information of the society, there are significant differences between oral and literate traditions. Writing made knowledge much less precarious than it had been in the era of dependence on the spoken word. Enormous effort was required simply to maintain the existing knowledge so that the subsistence economies of early societies could devote few resources into the expansion of knowledge. In preliterate societies the advances of knowledge, even substantial advances when they occurred, were often not noticed. The advancement of knowledge within the oral tradition occurred though gradual evolution as it was transferred from person to person or as it was publicly talked out. The advancement of knowledge was a communal process; there were no Newtons or Einsteins in oral cultures (27).

Writing stabilized, depersonalized, and objectified knowledge. In the oral tradition, the elder is venerated since it is he who is the source and receptacle of knowledge. There is no such thing as a fallacy of an "argument to authority" in oral culture. Words, and the information they constitute, take on a different character in an oral as contrasted with a literate tradition. For example, in Biblical times:

> The Israelite conception of "word" and particularly the "word of God" was not considered to be the mere verbalization or articulation of thought. Rather it was God himself, communicating and giving himself in self-realization. Dabar (the Hebrew equivalent of "word") is therefore a manifestation of God. In other words, "word" to the Israelites was something extremely personal, so that it would be correct to say that the communication of the word is actually the communication of the speaker him/herself (32).

Writing existed when Socrates was born in 499 BC, but the sprit of the oral tradition was still strong. Socrates spoke; Plato wrote. In the *Phae-*

drus Plato recounts how Socrates inveighed against writing as a means of advancing human knowledge. Knowledge, for Socrates, was not something which resided in the inert written word but only in the minds of humans. Socrates compared writing to a painting. While the artist's portrait stands before us as if alive, we cannot question it. In the same way, we cannot interrogate the book. The faces in a good artist's painting appear alive and:

> . . . seem to talk to you as though they were intelligent, but if you question them they maintain a most majestic silence. It is the same with words: they seem to talk to you as though they were intelligent, but if you ask them anything about what they say, from a desire to be instructed, they go on telling you just the same thing for ever. And once a thing is put in writing, the composition, whatever it may be, drifts all over the place, getting into the hands not only of those who understand it, but equally of those who have no business with it; it doesn't know how to address the right people, and address the wrong. And when it is ill-treated and unfairly abused it always needs its parent to come to its help.

After several centuries of life within a literate tradition, the disconnection of words from the living sentient being that produced them is accepted and even appreciated since it objectifies the information presented. Indeed, as citizens of a literate world we often turn Socrates' argument upside-down and tell the person who is concerned that their message may be misunderstood or misinterpreted to "get it in writing."

Writing did not eliminate talking but, as Ong points out, writing caused both an expansion of talking and a transformation of it. Writing was a phenomenon of urbanization. Writing occurred in compact settlements and people in these environments talked with one another more than those in scattered settlements; writing gave them more to talk about. Writing also transformed speech. It made possible highly complex and deeply organized treatises on topics which were not possible in an oral tradition and enabled a use of language to manipulate and organize thought in ways which were quite different and more powerful than that which could be done with speech. Having learned to express oneself in the manner which could be accommodated by writing, individuals could, and did, emulate these conceptual and semantic structures in speech (26).

The invention of school was a consequence of literacy. The development of schools as places removed from the primary productive processes of society is closely connected with the development of writing. Records of the first known schools date to 2000 BC in Sumer. These schools were a direct consequence of the need to teach cuneiform writing to a scribe class (26). Goody speaks about the creation of schools where children were removed from their families and placed under special authorities as "decontextualization" (10). In oral cultures, learning was largely experiential and integrated into daily life. One did not learn by reading written procedures and instructions but by observation and practice. A person could learn to speak by listening to others speak and by imitating their behavior, but learning to read and write could not be accomplished in the same way since writing and reading were activities confined to a scribe class. Thus, schools as places where learning was decontextualized or disassociated from the everyday natural life tasks of the individuals were required to provide the development of skills which required extraordinary means for them to be learned. With the advent of writing, words—both spoken and written—became more central to learning in contrast to learning by observing and doing.

It is fitting that like the invention of the first and second great codes, the time and place of the invention of the third and most recent code is also uncertain. The popular choice (at least in the United States) is Samuel Morse who on May 24, 1844, sent the message "What hast God wrought!" via telegraph. But there are other candidates in Russia, Germany, and England. Possibly the first was in Germany where in 1809 a "chemical telegraph" was displayed in Munich which sent electrical current through wires in a water container with each wire indicating a particular letter of the alphabet.

Around the time that Samuel Morse was working on his invention, an Englishman named Charles Babbage was deep at work on his Analytic Engine, the precursor of the modern computer; however, Babbage's Analytic Engine operated mechanically rather than electronically. Babbage saw a type of telegraphy similar to the one developed in Munich and understood the relevance of the use of electronics in his machine. But given the state of the art, this was impractical for him (13). In a little more than a century, however, the paths initiated by these two inventions would converge in the form of the ENIAC computer. This computer, which is generally acknowledged to be the first digital electronic computer, was developed by Mauchly and Eckard during World War II at the University of Pennsylvania. The information age had begun.

The terms "information society" or "information age" are buzzwords. They are widely used often with only a casual effort to unpack the meaning from them. Probably, for many, these terms mean little more than that computers and other associated technologies are an omnipresent feature of life and that most people will need to use them with considerable regularity. Yet, it is clear that a new manifestation of the human condition has emerged which is of a magnitude comparable to the two earlier advances in the construction of human culture.

The rapid advancement of information technology over the past few decades is one of the most dramatic episodes in the history of human ingenuity. As is well known, the power and performance of the laptop computer of today which sells for less than $2,000, is substantially more powerful than the mainframe computers of a couple of decades which sold for hundreds of thousands of dollars. Scholarship such as that provided by Ong (26) and Goody (10) shows clearly that the progression from an oral to a literate and from a literate to an electronic tradition changed the human condition. Each step has altered the relationship between the person and his/her own inner mental life. Also, each step has had enormous consequences on the amount and nature of the information within the culture. It is not difficult to recognize that a person living in rural Oklahoma has a different type of existence than one living in the inner city of Manhattan because of the difference in the physical environments. Similarly, changes in the intellectual environment of the magnitude that has occurred with the creation of speech, writing, and electronic information have had immense impact in shaping the way in which humans live their lives.

The most obvious implication of the information revolution is the expansion of knowledge. Walter Ong estimated that at the beginning of human history knowledge took from 10,000 to 100,000 years to double. Later it took from 500 to 1000 years to double. Currently, it is doubling in 15 years or less (27). Within the oral tradition, one person could, and did, commit to memory the totality of the knowledge of the society. Where is the person who could memorize all of what is known in our time? Within the literate tradition, it was possible for sensible people to take on the task of creating a set of books which contained the totality of human knowledge in an organized fashion. Who would set out to construct an encyclopedia which purported to be *everything* which is known in *all* fields of human endeavor? As knowledge expands because of information technology, it is information technology which offers the means to cope with the massive expansion of knowledge which is occurring. The knowledge which an individual has committed to memory, or the books he or she has read, are less and less a determinant of functional ability. Increasingly, it is one's ability to interact with the words, numbers, and pictures stored in computers in ways which result in informing (in the fullest sense of that word) him/herself which determines functional ability.

As was the case with the progression from an oral to a literate tradition, the new tradition does not replace but transforms the old. Word processing does not merely automate the process of writing; it transforms it. Jay David Bolter provides a detailed and thoughtful analysis of the impact of word processing on writing:

> How the writer and the reader understand writing is conditioned by the physical and visual character of the books they use. Each physical writing space fosters a particular understanding both of the act of writing and of the product, the written text. In this late age of print, writers and readers still conceive of all texts, of text itself, as located in the space of a printed book. The conceptual space of a printed book is one in which writing is stable, monumental, and controlled exclusively by the author. It is the space defined by perfect printed volumes that exist in thousands of identical copies. The conceptual space of electronic writing, on the other hand, is characterized by fluidity and an interactive relationship between writer and reader. These different conceptual spaces foster different styles and genres of writing and different theories of literature (1).

While epistemology, the study of the philosophy of knowledge, is an active interest of a small percentage of people, everyone carries with them a conception of the nature of knowledge. Writing, and more specifically the technology of the book, profoundly influenced the way in which people have thought about knowledge for several centuries. The structure of the book became the structure of knowledge. The book is linear. It is divided into chapters, each of which contains a unified and cohesive segment of the totality. The order of the presentation is governed by logic which yields one order of presentation. The book has heft and the words printed on a page have a permanence and a physical presence. These characteristics of the book became transposed to the conception of knowledge with cohesive and distinct disciplines, with a logical order to the structure of the discipline, and with durability.

Just as the traditions of the literate culture and the structure of the book shaped the conception of the nature of knowledge, the emerging traditions of the information culture are providing a new conception of the nature of knowledge. The metaphor for knowledge changes from that of the book to that of a colossal hypermedia stack. Knowledge becomes a network of concepts with many connective pathways. Linkages between concepts are formed on the basis of functional utility rather than on immutable and intrinsic logic. In the context of an electronic information tradition, knowledge is dynamic. Textbooks or reference books which are used for several years before a new edition is produced seem inappropriate, but editing or adding to an information in an electronic format is easily accomplished. The electronic tradition, like the oral tradition, is much more congenial to a communal approach to the construction of knowledge than is the print tradition. Just as there were no Einsteins or Newtons in oral cultures, the advance of knowledge in an electronic tradition is likely to involve fewer advances which are attributable to the work of a solitary genius.

Information technology not only affects what we know and how we come to know it, it also affects what we do. The need for any particular skill is contingent on the context of individuals. Information technology is causing some skills to become less valuable at the same time that new skills are becoming more valuable. Few people in our society rely on their ability to hunt for food to feed themselves. Today, one requires skills at being an effective shopper at the local supermarket. Old skills pass and new ones emerge. Many factory workers who worked with their hands and wrenches, drills, and welding tools no longer require skills with those tools but must now teach their hands keyboarding skills or work with computer programs that control machines that do what they once did with their hands. The value of being able to spell by memory every word a person uses in writing is less important when the individual writes on a word processor with spell check. The task of searching information bases did not exist in any significant fashion a few decades ago. It is now a skill of great value.

At the heart of the difference between a literate and an electronic culture (and certainly at the heart of the issue as it pertains to learning and schools) is the shift from a contemplative to an experiential method of learning. In a writing culture, human beings learn by pulling away from what is happening around them and reading about events, concepts, facts which another person has abstracted and structured. An electronic culture, on the other hand, puts the person in the midst of the experiences which often are raw, unprocessed and, to use computer lingo, are real-time. The orderliness and "one step back" character of reading is in contrast to the untidy and "plunge into it" nature of electronic experiences. Thus, we do not read about the Persian Gulf War; we experience it on CNN. The concern of many is that what comes to the person in electronic formats are only pictures which may have no meaning beyond the momentary visual or auditory stimulation. Such a criticism goes beyond television or multimedia and pertains to experience itself. Experience is nothing more—or less—than the images, sounds, smells, and feel of what is occurring. The old saying is: Experience is the best teacher. But experience is not an infallible teacher. Thinking and reflecting do not go out of the picture in experiential learning. Thinking, evaluating, and reflecting are all part of "learning from experience," but they are blended into the learning process in a more subtle, less conspicuous way than in instances of "book learning." The texture and rhythm of learning when mediated by electronic resources is in sharp contrast to that which occurs in the environment of the printed word. This is the fundamental "two cultures" problem of schools at present as literate tradition teachers try and too often fail to teach electronic tradition students.

Information technology has substantially elevated the importance of pictures in learning. Today most people learn about their world in pictorial form through television. Pictures are particularly potent in engendering an emotional response. A pictures of a starving child in Mogadishu or of students resisting repression in Tianamen Square has an immediacy of impact which surpasses many columns of print in a newspaper account of the same story. Increasing attention has been devoted to the use of visualization as a means of presenting in pictorial form vast quantities of information. The user of such information might drown in the sea of this information in verbal or quantitative forms. The use of pictures in learning is troubling to some people since there is fear that looking at pictures is an act which can be done without the mind engaged. Picture books are considered acceptable for very young children, but comic books have been discouraged, usually more because of their use of pictures to tell the story than because of the content of the story. Nevertheless, there is a rich tradition of scientists, designers, and artists who think with images, and the capacity of information technology to present still and moving pictures expands the palette for developers of learning resources. For those of us who have lived and learned in a literate culture, there is something unsettling if not invalid in the migration from learning with text to learning with pictures, but it is quite likely that people in the future will look back on the limitations of our bias toward text in much the same way that we have observed the bias of earlier generations to the spoken rather than the written word.

There is little in contemporary life which is not touched in some significant way by information technology. Clearly, it has caused a fundamental transformation of the way people work. In one sense the computer is the most recent of a long series of machines such as the cropping machines used in textile manufacturing in the early 19th century at the outset of the Industrial Revolution. Cropping machines (which incidentally were destroyed by the skilled workers in England who were being displaced by these machines in the Luddite incidents) and other machines such as the cotton gin, the steamshovel, and the drill press automated work that had required a strong back or a steady and trained hand. The computer is quite different from the machines of the Industrial Revolution. To use the words of Shoshana Zuboff (40), who provided a thoughtful analysis of the impact of information technology on work, it is a "smart machine" and as such began a new chapter with regard to the nature of work.

The "Management in the 1990s Research Program" at MIT issued a report called *The Corporation in the 1990s* (23). This report contains rich detail about the nature of the changes at the levels of production, coordination, and management of the workplace. The sweeping changes are visible to anyone who walks on the floor of a factory. One finds fewer people, and many of the workers are using robotics, process control instrumentation, and intelligent sensors. Less conspicuous are the changes in how those responsible for generating a profit think about their business. There is an expression used by some in the media production business, “I can give it to you cheap, quick, or good. Pick two!” What the business person hears is, “Our company needs to produce a quality product at low cost, and make a profit. Pick three!” Information technology is at the heart of the new conceptions about how to flourish—or at least survive—in a world of new expectations with regard to cost and quality. In the words of the editor of *The Corporation in the 1990s*, “Information technology has important general-purpose power to manipulate symbols used in all classes of work and, therefore, as an ‘information engine’ it can do for business what the steam engine did in the days of the Industrial Revolution.”

Just as information technology is the influential work tool of society, information technology is also the dominant source of recreation. Parents and teachers commonly decry the great amount of time which children and young people spend watching TV. But looking at a screen, be it a TV or a video game screen, is the overwhelming source of recreation for children and young people, just as TV is the major recreational activity of adults. Video games, like TV, are often criticized. But someone, and the someone is often a parent, likes video games enough to make Sega and Nintendo a multi-billion dollar industry (33).

It has been somewhat less than a half century since the first big and clumsy computers appeared on the scene, and in the succeeding years there have been continuing advances and an increasing pervasiveness of the technology. There is a curious similarity between the purpose of writing at its inception several thousand years ago and the purpose of the first computers a half century ago. Both writing and computers began with a limited role in human conduct. The first writing systems and the first computers were “number crunchers.” In both cases, they were used for numerical tasks, and also in both cases, the power of the symbol system which was developed gradually moved writing or propelled computers to a vastly expanded role. Even after several decades of plotting the growth of the expansion of computer technology, seasoned pros still can be surprised. Early in 1993 Bill Gates of Microsoft and Andrew Grove of Intel predicted PC sales of between 35 and 40 million, which was an increase from the 32 million sales in a good 1992 sales year. The actual sales were at 50 million, 25 to 40 percent higher than forecasted (9).

Efforts to predict the world that information technology will create can fall victim to a fatal trap if there is the assumption that at some point in the foreseeable future the process will have been completed. There is no reason to believe that anyone alive today will see the completion of this process or the achievement of stability with regard to the development of this technology, it will continue to be open-ended for generations to come. Nevertheless, there are several dominant themes which are likely to shape the expression of the technology in the years ahead:

- **Improvements in microprocessor design and reductions in cost.** The capability of microprocessors continues to increase as costs decrease. The first microprocessor was built in 1971 and in less than 20 years, by 1989, the first microprocessor to contain more than a million transistors was produced. By the year 1976, after five years of transistor production, the total of all the transistors manufactured by the computer industry was about 100 billion which is equivalent to the number of neurons in the human brain. Intel scientists predict a single chip that can hold somewhere between 50 and 100 million transistors will be produced around the turn of the century. With 100 million transistors on a chip, it would require only one 1,000 processors to produce a computer with as many transistors as neurons in the brain. Gelsinger and his colleagues at Intel contend that when systems with hundreds of billions of transistors become available early in the next century, it will then be possible to ask: “When will we put the first brain on a single chip?” (8).

  Even with the dramatic advances in chip design over the past two decades, the capabilities of existing hardware is a constraint in applications design. There remains a great gap between the way in which the mind processes information and the way in which this is done by computers. This gap will narrow with the improvements in chip design that will soon make today's supercomputers reminiscent of the Apple IIe. As this happens, the price of computing storage and speed will decrease. No one knows what a gigabyte of storage or 100 MIPS of processing speed will cost in the year 2000, but everyone knows it will be quite cheap and probably considerably cheaper than any current prediction.

Increasing the processing power of chips is not equivalent to increasing the horse-power of an automobile which has quantitative significance in terms of the speed with which the vehicle can carry weight. Increases in the processing power have qualitative significance in enabling new applications to be developed. While it is possible to extrapolate from existing applications and speculate about the improvements that will result from increases in processing power, no one knows what inventors will build when they can hold the processing power of hundreds of millions of transistors in their hands.

- **Networks.** It was only about a decade ago that battles were being fought between mainframe proponents and microcomputer proponents. With the increased capability of microcomputers, many (myself among them) were prepared to officiate at the funeral of mainframes. What many failed to see was the growth of wide area networks. Ultimately, in the contest between microcomputers or distributed computing and mainframes or central computing, the emergence of networks made both winners. The use of computers to create networks for communication and access to information has moved from being an important to a dominant theme in the use of the technology. Acronyms associated with networks such as BBS and FTP are migrating from computer insiders to the general population. By 1993, a little more than a decade after the first BBS or computer bulletin boards opened up in California and Chicago, there were more than 60,000 nationwide (34). The massive growth of the Internet demonstrates the rapidly growing interest in the use of networks. As of late July 1994, there were 3.2 million machines worldwide reachable on the Internet. This represents an 81 percent increase over the previous year. No one knows the number of people using the Internet, but it is many times greater than the number of attached machines.
- **Portability.** Advances in wireless technologies in the past few years offer the prospect of making use of the virtually infinite resources of the spectrum of electromagnetic vibrations. In the next few years advances in wireless technology along with the increased installation of fiberoptics will reduce the cost of transmission of information which requires larger bandwidth such as video and two-way communications. Andrew Grove of Intel put it succinctly, "You think computer prices are plummeting. Wait till you see what happens to bandwidth"(9).

  Of course, the elimination of wires also enhances the portability of devices that are already being miniaturized because of advances in chip technology. Smaller machines which are not tethered by wires also will be improved with better display capabilities. The display capability of a typical television set is roughly equivalent to 62 dots per inch. Screens with 200 to 300 dots per inch (which is equivalent to a laser print) will be available. Just as writing did not eliminate reading but transformed it, information technology will not eliminate reading on paper, but reading increasingly will be done using small portable display screens. Screens which display information at a quality level that is comparable to a well-printed color magazine at a cost per word that is substantially less than the cost of the same word printed on paper will have the effect of moving much of what is read to electronic formats. Given the fact that most of the information that is produced at the present time is already in electronic format, the extra step of printing it on paper will be reserved for those who want paper to satisfy emotional or particular practical needs.

- **"Everything is data."** From our vantage point, it is ironic that Mr. Morse's digital invention was swept away by Mr. Bell's analog device. The future for analog signals such as those used by television does not appear promising. The bifurcated world of computer data in digital format and television signals is ending. As one of my colleagues frequently reminds me: "Everything is data." The efficiency and utility of storage and transmission of information, be it pictures, sound, or words and numbers in digital format is substantially greater than in analog format. Analog is an appropriate technology for a 20th-century broadcast world, not a 21st-century network world. In *Life After Television,* Gilder puts it this way, "The computer industry is converging with the television industry in the same sense that the automobile converged with the horse, the TV converged with the nickelodeon, the word-processor converged with the drafting board, and digital publishing converged with the linotype machine and the letterpress"(9).
- **Applications.** The first applications for computers were directed in ways to manipulate numerical information. Statistical and other numeric processing software was the dominant use of the early computers. The computer was a super calculating machine. As the technology developed, new applications emerged. Applications such as word processing and spreadsheets did not represent new ways to do old tasks, but were new ways to do new things. Over the next several years there will be new software inventions which will go beyond simply improving existing applications (i.e., advancing from version 3.0 to version 4.0). New applications will continue to emerge. For example, there are efforts to develop applications such as idea processors which can be used to manipulate concepts, ideas, and thoughts in a way similar to the manner in which word processing enables the user to manipulate words. The development of specialized software to exploit the full potential of computer mediated group-work, generally referred to as groupware, has just begun. This is an area still waiting for the "killer application," or, more likely, the "killer applications." As primitive and cumbersome as virtual reality is at present, it will become more and more realistic and adept at tricking the mind into believing that what exists only in cyberspace exists in real space. Visual, auditory, olfactory, and tactile perception of environments generated from strings of data will become so lifelike that the differences between virtual reality and "real" reality will seem to be a trivial distinction. There is certain to be a market for virtual reality for pornography and for violence. The fondest sexual and homicidal fantasies will be achievable without fear of criminal indictment. Some educational applications are obvious, such as the use in language learning by enabling the person to learn French in virtual France, or to learn about astronomy by taking a trip through space, or to understand human biology by engaging in an expedition into the human body. Beyond such obvious applications as these there is also an unknown continent of applications of this simulation and virtual reality for learning purposes yet to be explored.
- **Information technology vs. computers.** Throughout this document, the term "information technology" has generally been used rather than "computers." Thinking about the impact of this technology is inordinately truncated if one thinks about it in terms of the microcomputer. Microcomputers are only the current and most prevalent manifestation of the handling of electronic information. Over the next years, multiple and diverse machines will emerge and evolve and it will be increasingly clear that information processing represents a category rather than an entity.

The American public school has remained generally impervious to the impact of information technology. Much of the discussions about information technology and schools has focused on the question: How can information technology help school personnel to achieve the goals and purposes of schools? In this formulation, schools are the "horse" and information technology is the "cart." Yet in reality, the horse and the cart are reversed.

For previous generations, the American system of schooling was seen as one of the great accomplishments of this nation. Such is no longer the popular perception, but in reality, it is not that schools have deteriorated but that the world has changed around them, making much of what occurs in schools anachronistic. The impact of information technology on schools transcends *what schools do* and affects *what schools are*.

THE AMERICAN PUBLIC SCHOOL AS AN INSTITUTION

Few aspects of life are as commonplace as schools. School buildings are the one place where everyone in society has spent time, some as much as 20 or more years. If a person becomes a parent, he or she is back in school again as they tend to the education of their child. Everyone knows what goes on in schools. In this context, it might seem quite peculiar to ask the question: what is the American public school? This question needs to be answered, not it terms of an inventory of what students and teachers do inside of classrooms, but in terms of what the American public school has meant to people in American society with regard to the learning and socialization required by children.

The American public school is an institution, and the term "institution" is key to understanding what it is as well as grasping the changes which impinge on schools as a result of information technology. Connotatively, the term "institution" carries with it a vague honorific meaning suggesting something of importance and permanence. Often there is little more than superficial use of the term institution as an explanatory concept, even though understanding the American public school as an institution is very helpful in any effort to make sense of what the public school is, why it is what it is, and how it fits into American society.

Many who believe that the school must be reformed, restructured, reengineered, or reinvented draw upon the recent experience of American business and industry to indicate what needs to be done. There is, however, an important distinction between the school and the firm. Both the school and the firm are organizations. As such, both are cohesive entities comprised of elements, each of which performs a specialized function necessary to accomplish the goals for which the organization was formed. Yet, the firm and the school represent two different types of organizations. John Meyer and his colleagues have provided a helpful analysis of the difference between organizations in technical contexts, such as the firm, and organizations in institutional contexts, such as the school:

> Formal organizational structures arise mainly through two processes. First, complex technologies and social environments with complex exchanges (such as markets) foster the development of rationalized bureaucratic structures to efficiently coordinate technical work . . . Second, institutional structures emerge that define given types of roles and programs as rational and legitimate. . . . The emergence of the factory reflects the first process, and the emergence of the school reflects the second (22).

The "technical organization" exists to *do* something. The purpose of the firm as an organization is to produce goods and services in a profitable manner. The term "bottom line" (which has become a popular metaphor) is far more than a figure of speech for the firm. The figure at the bottom of the accounting ledger is the critical criterion, accepted by all within the firm, of the organizational health of the firm. The organizational structure is effective to the extent that the organization is able to do what it needs to do, i.e., produce marketable goods or services at a profit. While the firm is affected by social values which go beyond the specific production or service goals of the firm (such as environmental concerns or racial or gender equity), these are not the *raison d'être* of the firm, but facts of life with which it must contend, grudgingly or willingly.

The school as an organization exists in an institutional context. The "institutional organization" exists to *be* something. It is in this sense that Meyer and Rowan point out that "modern schools produce education for society, not for individuals or families" (21). This is not to deny that individual teachers or administrators strive to—and do—provide services for children and their parents. Rather it means that for the school, unlike the firm, the beliefs shared by members of the society of the role it plays for the perceived well-being of society is of critical importance. The extent to which it is perceived to be meeting its social mandate is the "bottom line" of the organizational health of the school.

Shared beliefs are more than a desired feature of a society, they are an absolute necessity. Community or society disintegrates in the absence of a core set of accepted beliefs. Sociologists refer to the shared beliefs as the "rational myths" of society which are the structural framework of institutions (22). They are myths, not in the popular use of that term as being untrue, but in the sense of being widely and deeply held by members of the society. The myths are the ideological sinew which hold together the individuals as a community. The issue of the truth or falsity of the myths is irrelevant since the myths are value statements which do not lend themselves to empirical validation. "The beliefs are rational in the sense that they identify specific social purposes and then specify in a rule-like manner what activities are to be carried out (or what types of actors must be employed) to achieve them" (37).

One of the most important tasks of society is to ensure that each successive generation acquires the knowledge, technologies, skills, customs, and affects which they require to maintain the society. In the last century a belief structure was put into place which became accepted about the way in which children would be educated. Schools had existed from the early days of colonization, but early in the last century the American public school as an institution was created.

From 1830 to 1860, the size of the United States grew by 1,234,321 square miles, and the population grew from 12,866,020 to 31,443,321. Only 7.2 percent of the population lived in urban areas in 1820, but by 1860 this had risen to 20 percent. In 1820 there were only 12 cities with a population of 10,000 or greater. By 1860, there were 101 United States cities with a population of 10,000 or greater, and eight of them were larger than 100,000. In 1826, 10,837 immigrants were admitted to the United States. Of the 10,837, most (7,708) were from England or Ireland. During the decade of the 1850s, more than 3,000,000 immigrants entered the United States, with large percentages from Southern Europe.

Industrialization, urbanization, and immigration transformed American society and spawned problems for a nation in transition. Cities became engines of productivity with concomitant disease, poverty, and crime. Many persons felt that homelessness, vice, and alcoholism were out of control. In the 1830s, there were numerous acts of mob violence. The objects of the wrath of mobs were often immigrants or Catholics. By mid-century the Know-Nothing Party, with its platform of bigotry, was the fastest growing political party in America. The success of the Know-Nothing Party was a consequence of the widely held opinion, even by many who did not affiliate with it, that the "American way of life" was in jeopardy.

Coincidentally, with the great social distress in the nation, a fever for reform swept through the country. There has never been a period of more intense reform spirit in America than the second quarter of the 19th century. The reform agenda ranged across a wide range of causes: abolition, temperance, women's rights, vegetarianism, prisons, and treatment of the insane. Organizations sprang up which reflected the fervor and optimism of those who began them: Society for the Suppression of Vice and the Promotion of Good Morals; The Friends of Universal Reform; The Boston Society for the Moral and Religious Instruction of the Poor; The New York Association for the Relief of Respectable, Aged, Indigent Females; and the American and Foreign Anti-Slavery Society to name but a few. Dorothea Dix traveled thousands of miles in her efforts to reform the treatment of the insane. Susan B. Anthony worked for the cause of women's rights and temperance. William Lloyd Garrison took up the cause of abolition.

The theme which transcends the specifics of the reforms of the 19th century was the establishment of social institutions to create a more perfect society. They believed that the welfare of the individual was enhanced and protected by social institutions rather than threatened by them. The optimism of the reformers was extended over a wide-ranging array of new institutions. The insane asylum was created not as a last resort to lock away the disconcerting and frightening specimens of humanity; rather the asylum was a manifestation of the belief that a properly constructed asylum could cure virtually any incidence of mental illness (35). Other institutions such as the reformatory and the penitentiary were based on the same optimistic beliefs about the potency of these organizations to change people and solve social problems.

Education was one of the focal points of the early 19th-century reform movement. The more perfect society which the reformers sought to construct had clear and obvious educational implications. Though the educational reform movement was centered in New England, there were persons throughout the United States who dedicated their lives to the creation of a new and better way to educate American youth. James G. Carter and Horace Mann in Massachusetts, Henry Barnard and Thomas H. Gallaudet in Connecticut, Calvin Stowe in Ohio, John D. Pierce in Michigan, John Swett in California, Calvin H. Wiley in North Carolina, and Robert J. Breckinridge in Kentucky were some of the most prominent educational reformers. They were joined, not only by common cause, but by association and interaction. They read one another's books and speeches, corresponded, and came into contact with one another in the many educational organizations and associations which flourished.

The 19th-century reforms were a reaction to the approach to education which had prevailed in the United States from the earliest days of colonization to the early years of the 19th century. Education was an important theme in the earliest days of American colonization. The first European settlers in America came to the New World at a time of a great information revolution in Europe. They had left England in the midst of an information explosion. In the century prior to the emigration to America there had been a tremendous expansion of the literacy with the rapidly spreading availability of books in the vernacular. As a consequence there was less dependence on the oral tradition and a greater reliance on books for every facet of life. There was a profusion of books pertaining to all aspects of life, from agriculture to personal conduct. The cost of books was such that for the first time in history the recorded word was accessible to a mass market. The abundance of valuable information which became available through the advances in printing technology placed increasing importance on literacy. Literacy was required if one was to be able to read the various manuals, almanacs and technical information in all fields which was becoming increasingly abundant.

The attitude of people in the 16th century toward their information revolution was similar to the attitude of people in the 20th century to our own. Some rued it, some were oblivious to it, but many, especially middle class townspeople, saw it as a basis for a better life. Robert Ryece, a friend of John Winthrop, the great Puritan leader, wrote to him on the eve of his trip to American on the *Arbella*, "How hard it will be for one brought up among books and learned men to live in a barbarous place where there is no learning and less civilization" (4). As they left civilized England for the untamed New World, there was fear of losing the culture of the homeland. Education was the prophylactic against barbarism. Thus, the Puritans brought their books with them to the New World, but of even more significance, they brought with them a belief that education was an important means in achieving prosperity on earth and salvation in heaven.

The home was the prime educational agency of early American society, and the prime agent for education in the Puritan community was not the state or the church but the family. This did not mean that the parents were the sole teachers of their children; rather, many arrangements were made, depending on the circumstances, for education to occur, and indeed the colonists were prone to establishing schools. In essence, everyone in the Puritan community was potentially a teacher. Children acquired instruction:

> Anywhere and everywhere, not only in schoolrooms, but in kitchens, manses, churches, meetinghouse, sheds erected in fields, and shops erected in towns . . . pupils were taught by parents, tutors, clergymen, layreaders, preceptors, physicians, lawyers, artisans, and shopkeepers . . . (4).

The manner in which education in the home or the workplace occurred was informal and had to be worked into one's own life as the rhythm of daily life permitted. It was common for children to learn to read, write and cipher within the home with parents, older brothers or sisters, other relatives, or neighbors providing the instruction. For example, as a young child near the beginning of the 18th century, Horace Mann learned to read by following his sister around the house as she did her chores reciting from a copy of Noah Webster's grammar (20). Ministers, who had skills in classical languages, would frequently tutor children who sought entrance to college since knowledge of classical language was the 19th-century equivalent of the SAT for college admission.

Proprietary schooling abounded. There were many persons available to those who were able to pay for schooling or tutoring. Tutoring could be purchased for primary instruction in reading, writing, and arithmetic, and for more advanced instruction in Greek, Latin, geometry, surveying, navigation, and bookkeeping. Wealthy parents might hire a teacher to extend, supplement, or replace their own instruction. The private master would provide instruction for all of the employer's children along with the children of other relatives or friends. Those who wished to advance their position through more advanced learning could secure the services of a teacher, either as a private student or in a school in the tutor's home or business.

Apprenticing was also a very important means of professional and vocational training. Apprenticeship was the way in which persons were trained in agriculture, shopkeeping, manufacturing, the skilled trades, and the professions of medicine and law. In the case of medicine, there was a rather standard form of apprenticeship. In the case of law, the apprenticeship was varied depending on the proclivities of the master (5).

Thus, the flavor of education in the 17th and early 18th centuries was characterized by two elements: personal responsibility and diverse means. It was up to the individual to determine the extent of education necessary for self and children. It was incumbent on the individual to achieve the required education in a manner which provided the best fit between one's life circumstances and educational goals. Writing about the colonial and early national era, Cremin says, "Variegation, then, was the rule, and with it improvisation, imitation, trial and error—whatever historical development there was ended up anything but uniform and linear" (6). But then over the span of 30 or so years at the mid-point of the 19th century a radically different form of education emerged in America:

> The haphazard arrangements of the 17th, 18th, and early 19th centuries cannot be considered true progenitors of the school systems we know today. For by the latter part of the 19th century the organization, scope and role of schooling had been fundamentally transformed. In place of a few casual schools dotted about town and country there existed in most cities true educational systems: fatefully articulated, age graded, hierarchically structured groupings of schools, primarily free and often compulsory, administered by full-time experts and progressively taught by specially trained staff. No longer casual adjuncts to the home or apprenticeship, schools were highly formal institutions designed to play a critical role in the socialization of the young, the maintenance of social order, and the promotion of economic development (15).

The 19th century reformers saw the variegated educational situation of the 18th century when education occurred in many venues in many ways as dysfunctional. Yet, the approach to education which had prevailed from the earliest days of the colonial era through the first years of the republic had served the American people well. The dissatisfaction with the old approach to education was a consequence of the great changes which were occurring in the nation and the emergence of new beliefs, a new rational myth, about how children should acquire the cultural legacy of their forebearers. If there was one word which caught the essence of the changes the reformers sought to establish it was "system." In the words of one of the reformers, James Carter, the reform movement sought a "consistent system fully developed" (2). The 19th-century reformers created "the school system" not only in the jurisdictional sense as used to refer to a particular school district but also as the system of schooling which was to be the manner in which the society would handle the commonalities of human action associated with the transmission of the knowledge, skills, dispositions, and sensibilities required to maintain the society.

Nineteenth-century Americans were greatly influenced by European education which in the late 18th century was in the early stages of the educational reform which would spread to the United States. A number of reports written detailing the successes of European education achieved a wide and influential readership in the United States. The fundamental conception of the reform movement in Europe was the establishment of the school as the primary social agency for education of the young. This belief grew out of the concern about the neglect of education of the children of the peasants. Concomitantly, there was a shared belief among those involved with school reform that schooling, if systemic and systematic, could produce young people with the knowledge and disposition which were requisite to ensuring economic prosperity and domestic tranquillity. There was, they believed, a pedagogy which rested on a scientific foundation which could ensure that the content the state needed to inculcate in each child could be accomplished. The weak laws requiring parental or citizen support of schools were replaced by laws which established state support of schools and, by the turn of the 20th century, compulsory school attendance.

The idea that the school has had more responsibility thrust on it over the years is inaccurate. The broad nature of the mission of the school was not constituted by accretion but by charter. Calvin Stowe, the husband of Harriet Beecher Stowe, was one of a number of Americans who went to Europe to examine European education and to report on it to the Ohio legislature. His report was presented to the governor of Ohio in 1837. It was widely distributed and became quite popular. He wrote as follows:

> The children must be given up implicitly to the discipline of the school. Nothing can be done unless the teacher has the entire control of his pupils in school hours, and out of school too, so far as the rules of the school are concerned. If the parent in any way interferes with, or overrules the arrangements of the teacher, he may attribute it to himself if the school is not successful (38).

Similarly the words of Horace Mann from his third annual report to the Massachusetts Board of Education express the conviction that the school was the instrument to be used by society to maintain society:

> Common Schools derive their value from the fact that they are an instrument, more extensively applicable to the whole mass of the children, than any other instrument ever yet devised. They are an instrument, by which the good men in society can send redeeming influences to those children, who suffer under the calamity of vicious parentage and evil domestic associations. The world is full of lamentable proofs, that the institution of the family may exist for an indefinite number of generations, without mitigating the horrors of barbarism. But the institution of Common Schools is the offspring of an advanced state of civilization, and is incapable of coexisting with barbarian life, because, should barbarism prevail, it would destroy the schools, should the schools prevail, they would destroy barbarism (19).

The belief that the school could accomplish the intellectual and socializing functions of education was quite functional to a nation increasingly industrial and urban. The conception of schooling as *the* place rather than *a* place where children acquire the knowledge and skill they will require to become effective members of society has remained the prevalent belief for a century. Even though the existence of many nonschool learning resources exist, and even though many individuals can speak of the impact of these resources in their own lives, they have typically been perceived as ancillary to schooling as the means for educating children and youth. The educated person has been the schooled person. We even lack good terms to refer to the array of educational resources such as books, TV, clubs, movies, friends, parents, and other adults which may make important contributions in terms of the individual's knowledge, skills, and attitudes. They are referred to as "nonformal education" and are thus defined in terms of what they are not in reference to schooling. Even those who do not esteem their schooling tend to answer the question, "Where did you get your education?" by naming a school. Life is divided into two segments. The first segment is the period of schooling. Then there is a commencement or a beginning of the second segment when the individual is expected to become an active and productive member of society.

Much as the economic structure of society rests on the belief that coins and bills are more than bits of metal and paper, so too a sustaining belief maintaining the school structure is that certificates, diplomas, and degrees are more than attractive documents and that they certify competence. The issuance of official certificates as social passports both validates the school and is validated by the school. Certification informs the individual of his or her abilities as assessed by the school, but also, and most importantly, informs society. As long as the school is empowered to issue certificates which affect social status and economic mobility, the school will need to be taken seriously whether or not the individual or their parent perceives he or she has received adequate services. The power of schools to "mint" social currency is significant only as long as the currency is valuable. The accreditation of schools, state certification of teachers, and standardization of the curriculum constitutes the ways in which the state attempts to ensure the value of diplomas.

The reformers believed that a critical requirement for an effective system of education was teacher training. In one of the most important of the European reports which were so widely read by educational and political leaders, Victor Cousin, who had been commissioned by the French government to produce a report on Prussian schools, provided a laudatory description of the Prussian school system and included a lengthy description of teacher training. Cousin argued that teacher training was an essential aspect of the effectiveness of their schools. The skill and demeanor of the teacher was the critical element in achieving the change which was required.

The effort to establish state-supported normal schools in the United States began in the 1820s and many engaged in the reform effort saw this as the keystone of the reform movement. James Carter, a member of the state legislature in Massachusetts, was one of the leaders in the establishment of normal schools in that state. In 1824 and 1825, Carter published a series of essays in the Boston Patriot arguing for normal schools and explaining why state support was appropriate and necessary. In his words:

> It will do but little good, for example, for the legislature of the State to make large appropriations directly for the support of schools, till a judicious expenditure of them can be ensured. And in order to [do] this, we must have skillful teachers at hand. It will do but little good to class the children till we have instructors at hand. It will do absolutely no good to constitute an independent tribunal to decide on the qualifications of teachers, while they have not had the opportunities necessary for coming up to the proper standard. And it will do no good to overlook and report upon their success, when we know beforehand, that they have not the means of success (2).

The champions for teacher training did not come from the ranks of the current teachers and administrators but rather were a cadre of politicians and religious leaders. One very conspicuous figure in the history of normal schools was the Rev. Charles Brooks, who traveled from town to town in Massachusetts lecturing for state support of normal schools. Brooks organized a series of conventions and provided a platform for notables such as Daniel Webster and John Quincy Adams, who also spoke to the need for normal schools. Rev. Brooks, who had campaigned tirelessly for normal schools, stated the underlying conviction that had motivated him and the others who created the normal school: “As is the teacher, so is the school” (18).

The campaign in the Massachusetts legislature for state support of schools to prepare teachers gathered considerable momentum in the late 1820s. In 1827, Rep. Carter, who chaired the House Committee on Education, presented a report to the legislature that called for establishing a “Seminary for the Instruction of School Teachers.” Carter’s proposal failed by one vote. The debate continued, and 10 years later, on April 19, 1837, the legislature established a Board of Education. Creation of the board proved significant in the development of normal schools because Horace Mann (who was then serving as President of the Massachusetts Senate) was chosen to lead the board. Mann believed in the need to create a system to prepare teachers, and he committed himself without reserve to the success of the normal school venture. At one point, when funds for the normal school effort were short, he sold books from his personal library to raise the needed money.

There was considerable opposition to the founding of normal schools, but with Mann’s leadership, and with a gift of $10,000 from Edmund Dwight, a member of the state board, the forces in the legislature arrayed against normal schools were neutralized. A year later, members of the Massachusetts legislature attempted to end state support of normal schools. The opponents of the normal schools considered them unnecessary, arguing that anyone who had been taught would know how to teach (18). In a letter to Henry Barnard in 1851, Cyrus Pierce, the principal of the first normal school at Lexington, Massachusetts, explained what he had hoped to accomplish. He agreed that teachers may be able to acquire by trial and error over time the skills and powers they need to teach effectively, “but while teachers were thus learning, I was sure that pupils must be suffering” (34). The normal school would ensure that “teachers may be prepared to enter on their work, not only with hope, but almost with assurance of success” (34) A substantial effort in the Massachusetts legislature to rescind the normal schools and to return the unused portion of Dwights’s fund to him failed, and they continued to spread throughout Massachusetts and to other states.

At its inception, teacher training was disassociated from higher education. The normal schools were more like secondary schools than colleges, and considerable emphasis was placed on equipping students with knowledge of the content they were expected to teach. While a number of normal schools would eventually evolve into colleges and universities, the initial connection between teacher education and higher education came through a different route. Chairs in didactics or pedagogy began to be established in American universities in the last quarter of the 19th century. By 1892 the United States Commissioner of Education reported that there were chairs of pedagogy in 31 institutions, chairs of pedagogy combined with other disciplines such as philosophy or mental science in 45 others, and lectureships in an additional eight universities (28).

As early as 1890, New York University had established a School of Pedagogy which offered courses leading to a Master of Pedagogy and Doctor of Pedagogy degrees (28). The introduction of chairs and coursework in pedagogy was met with staunch critics in the university who considered such to be insubstantial or inappropriate for university study. Abraham Flexner, who had led efforts to reform medical education, became involved in efforts to install the study of pedagogy at the university level. In 1919 he was successful in securing foundation funding for the founding of a graduate school of education at Harvard. A decade later, however, Flexner had come to agree with critics that the instruction being provided at schools of education lacked academic rigor and had degenerated into a focus on simple practical problems which could be solved by “experience, reading, common sense, and a good general education”(30). Flexner worried that the nature of programs in schools of education would dissuade the intellectually competent from entering. Despite the efforts of critics, teacher training and other related programs such as those for school administrators, counselors, curriculum specialists, etc., continued to develop in universities, and many normal schools continued on a path which was to make them into universities. The goal of people like Mann, Carter, and Brooks for universal teacher training was realized, but the benefit of the training in terms of the improvement of schooling has been an issue of considerable debate from its inception to the present time.

So it was that the great reforms of the 19th century institutionalized schooling. Eventually all of the major aspects of the changes they sought were achieved. State departments of education were established which regulated school programs by establishing curriculum requirements and the licensing of teachers. States required local districts to provide free elementary and secondary schools and enacted compulsory attendance laws. Standards for the school buildings and their furnishings became established. Specialized training and licensing was required for those seeking to work as teachers. Districts developed standardized and age-graded curricula. Grouped instruction replaced the method of recitation. Textbooks were provided to students. Centralized control at the district level over building school sites was inaugurated. The concept of a public school system was new and strange to many a 150 years ago. It came to be taken for granted, even axiomatic. Yet, new beliefs about the nature of knowledge, which were a consequence of information technology (discussed above) and changes in understanding about learning, which also are stimulated by developments in information technology (discussed below), both challenge the structure which Mann and his colleagues put in place.

THE HUMAN AS A NATURAL LEARNER

There have been many answers to the question: What distinguishes human beings from other forms of animate life? For Plato, the human was characterized as a featherless biped. For the English essayist William Hazlitt, the human was the only creature that laughs and weeps. In technical terms, the human species is called *homo sapiens*, man the wise. The capability of the human to think, learn, and acquire knowledge was determined to be the characteristic that distinguished the human being from other primates. Other animals learn, as is evident from any trip to the circus, but no other form of life on earth exhibits cognitive capability comparable to the human being. Humanness resides in the central nervous system.

The ability to learn is not an acquired but a natural capability for humans. The human being is a learner from the moment of birth until the moment of death unless such is precluded by some brain abnormality. In the first hours after birth, the infant learns to suckle at the breast or bottle. Very quickly, the baby learns to discriminate his or her mother's face from other faces. The child will learn motor skills such as eating with table utensils, walking, and cognitive skills such as speaking, and social skills such as acceptable and nonacceptable ways of dealing with others as well as distinctions in behavior appropriate for the different people with whom he or she comes into contact. The small child learns a language, and, in many societies, may learn more than one language. Children acquire information and skills whether or not they are prodded or deliberately assisted by parents or other adults. Anyone who has spent any time watching a child cannot help but conclude that learning is a natural process.

In thinking about the human as a natural learner it is important to keep two things in mind. First, "learning" is not an honorific but a descriptive term. To say that the human being is a learner is not *per se* to pay a compliment. People learn bad things as well as good things. Children learn language, mathematics, how to play the piano, etc., but they can also learn prejudice, pot smoking, how to hot wire and steal cars, etc. Learning the wrong things is not necessarily a less impressive task when judged from the complexity of the learning task. It is, for example, probably easier to learn the occupation of a sales person in a fast food restaurant than to learn the occupation of a successful car thief. Second, to say that individuals are natural learners is not to imply that all demonstrate this capability to the same extent. People do learn how to learn and can become more or less interested in learning and more or less effective in the process.

In the past century there have been thousands of studies of human learning. The vast preponderance of these studies has focused on learning in schools, and since a substantial proportion of the population of school-aged children have problems learning in school, it is understandable that much of the literature has been directed to the nature of learning pathologies. Much less attention has been devoted to understanding natural learning, or learning in those instances when the process is not structured and regulated by others but is woven into the life situation of the person. In these situations, learning occurs even though there is not someone formally designated as teacher directing the process.

In a small book written three decades ago called *How Children Learn* (12), John Holt discusses how children learn when there is minimal or no adult intervention. Holt drew upon his experiences as a teacher in a fifth-grade classroom, but he was less interested in understanding how children learn when the process is prescribed to them by their teachers than in observing how children learn when they are not required to follow rules of the process established by the adults in their environment. Holt sums up his conception about the natural learning style of young children in the following passage from his book:

> The child is curious. He wants to make sense out of things, find out how things work, gain competence and control over himself and his environment, do what he can see other people doing. He is open, receptive and perceptive. He does not shut himself off from the strange, confused, complicated world around him. He observes it closely and sharply, tries to take it in. He is experimental. He does not merely observe the world around him, but tastes it, touches it, hefts it, bends it, breaks it. To find out how reality works, he works on it. He is bold. He is not afraid of making mistakes. And he is patient. He can tolerate an extraordinary amount of uncertainly, confusion, ignorance. He does not have to have instant meaning in any new situation. He is willing and able to wait for meaning to come to him—even if it comes very slowly, which it usually does (12).

One of the places where there is substantial and serious work currently underway to understand learning as a natural process is the Institute for Learning Sciences at Northwestern University. The Institute was established in 1989 with sponsorship provided by Anderson Consulting and Ameritech. The staff includes 21 faculty and researchers, 42 content specialists and programmers, 50 graduate students, and 20 interns and visiting staff. The Institute is dedicated to the task of investigations of human learning as a natural process and to make use of the knowledge obtained from these investigations to construct new means for improving learning in the workplace and then in the schools.

Roger Schank, the Institute director, along with Chip Cleary, one of his graduate students, authored a "hyper-book" which is available on the World Wide Web titled "Engines for Education." This book presents their ideas about what is wrong with education, and the role of educational technology in reforming schools. The book's perspective on natural learning is similar to Holt's. Like Holt they see the type of learning which occurs in schools as dysfunctional:

> In public schools from first through twelfth grade, much of the classroom routine is shaped by an emphasis on rote learning, a strict adherence to standardized textbooks and workbooks, and a curriculum that is often enforced with drill and practice. The methods and the curriculum are molded by the questions that appear on the standardized achievement tests administered to every child from the fourth grade on. Success no longer means being able to do. Success comes to mean "academic success," a matter of learning to function within the system of learning the "correct" answer, and of doing well at multiple choice exams. Success also means, sadly, learning not to ask difficult questions. When we ask how our children are doing in school, we usually mean, "are they measuring up to the prevailing standard?" rather than, "are they having a good time and feeling excited about learning?" (36).

Some caution must be exercised in overdrawing the distinction between school and non-school learning or in romanticizing the child as Holt does. There are classrooms where what is happening for children looks much like a natural learning situation, and it is much easier to know what is wrong about schools than it is to do what is right. Nevertheless, the conditions listed by Schank and Cleary such as standardized curriculum, grade level expectations, as well as an increasingly extensive amount of information which teachers are expected to "cover" create an environment for learning which, too frequently, does create a situation where there is so much to teach that there is no time to learn.

It is not a coincidence that two recent books on learning and technology, one by Donald Norman and the other by Seymour Papert, give considerable attention to informal or natural learning. For those accustomed to "cruising the Internet," "just in time learning," hypermedia, and virtual communities, school or formal learning is far too confining. Interest in using technology in instructional applications is not new. Sixty-eight years ago S.L. Pressey published a paper called "A simple apparatus which gives tests and scores and teaches" (31). In this paper Pressey described the plan for a machine which would be used as an "automatic teacher." It makes use of a typewriter apparatus to display questions and to provide feedback for correct or incorrect answers. Computer technology enables the production of more sophisticated versions of Pressey's "automatic teachers." These applications, while employing more elaborate graphics and more advanced interactive procedures, are fundamentally similar to Pressey's "automatic teacher" and many come out of a behaviorist, programmed learning, orientation. Increases in storage, display, and processing power of computers systems provides developers with the capability to go beyond the design of teaching machines and to create "learning machines" or, to use Papert's term, "knowledge machines." Such applications put in the hand of the user a rich informational environment which is accessible in a way which accommodates the interests of the user. "Learning machines" are based on an orientation which put the learner in control of the learning process and which is compatible with the orientation of natural learning. Early examples of these applications have appeared in the past few years in the form of various multimedia applications.

In his book called *Things That Make Us Smart* (24), Donald A. Norman cautions that multimedia technology can be used to provide applications that epitomize the worst of what is wrong with school learning or the best of what is possible with natural learning. Norman distinguishes between school learning and natural or informal learning (Table 1).

Norman cites the work of Mihaly Csikszentmihalyi who writes about "flow experiences." Flow experiences occur when the person is totally engaged in the task at hand. Teachers may tell their students to "Pay attention!," and while such an admonition may cause the student to *look attentive*, there is no assurance that the student will *be attentive*. The flow experience can only happen when the goals and challenge of the task captures the attention of the individual. Many observers of life in classrooms as well as teachers have expressed concern about the lack of engagement of students in what they are being told to learn. The lack of engagement of students in their instruction evident in many formal learning situations, kindergarten through college, is the antithesis of the "flow experiences."

Seymour Papert's book, *the Children's Machine* (29), is subtitled "Rethinking School in the Age of the Computer." Papert contrasts two different orientations to education—"instructionism" and "constructionism." Instructionism is the belief that the way to achieve better learning is to teach better. Constructionism, on the other hand, conceives of learning as a manipulative and building process. It draws a direct connection between construction in the physical and mental domains, and sees learning to be an activity involving the creation of mental structures by the learner which organize and synthesize the information and experience which the individual encounters in the world. Papert, similar to others who have dealt with the topic of natural learning, emphasizes concrete or experiential learning. He calls for learning which is rooted in concrete experiences rather than that which exists as free-floating abstractions. Perhaps one of the most radical of the assumptions of this perspective is that children can be trusted to find the knowledge they need. If one conceives of learning as an activity which is repugnant to the individual or if one believes that that there is a package of content which can and must be installed into the minds of all students, then trust in the learner is unwarranted. If these two conceptions are rejected, as they are by people like Papert, Holt, and Schank, then trust in the learner is quite appropriate. The task for those involved with the education of the young, as Papert presents it, is to see to it that children are supported materially, psychologically, and intellectually in their efforts to learn. He contends, “The kind of knowledge children need most is the knowledge that will help them get more knowledge”(29).

Holt, Schank, and Papert are only the most recent of a long line of persons to be aware of the discrepancies between school learning and learning as a natural human phenomena. Rousseau published *Emile* in 1762 and Pestolozzi opened a school at Yverdon in 1805. Rousseau as a theoretician and Pestolozzi as a practitioner gained a high degree of recognition for their work. In both cases, they presented a conception of learning which placed emphasis on the interest and experience of the child and saw the learning of the child rather than the didactics of the teacher as the key to the process. Pestolozzi’s school was visited by the czar of Russia and by the kings of Spain, Holland, Prussia, Denmark, Wurtenberg, and Saxony.

John Dewey, who had the misfortune of having his work become popular mainly in the form of interpretations developed by his disciples who “watered-down” and sanitized his ideas, saw this issue clearer than most and presented it as forthrightly as anyone almost a century ago:

> What is learned in school is at best only a small part of education, a relatively superficial part of education; and yet what is learned in school makes artificial distinctions in society and marks persons off from one another. Consequently we exaggerate school learning compared to what is gained in the ordinary course of living. We are, however, to correct this exaggeration, not by despising school learning, but by looking into that extensive and more efficient training given by the ordinary course of events for light upon the best ways of teaching within school walls. The first years of learning proceed rapidly and securely before children go to school, because that learning is so closely related with the motives that are furnished by their own powers and the needs that are dictated by their own conditions. Rousseau was almost the first to see that learning is a matter of necessity; it is a part of the process of self-preservation and of growth. If we want, then, to find out how education takes place most successfully, let us go to the experiences of children where learning is a necessity, and not to the practices of schools where it is largely an adornment, a superfluity, and even an unwelcome imposition (7).

It is not remarkable that the contrast between learning inside and outside of schools has been observed by a long line of educational practitioners and theoreticians since the differences are conspicuous to the reasonably careful observer. John Dewey’s disciples, most notably William H. Kilpatrick, attempted — and generally failed — to have their cake and eat it too. They sought to implement the conceptions of Dewey about natural and experiential learning while keeping intact the essential conventions of the system of schooling which by the early part of this century was well accepted. As information technology causes more and more of the agenda for learning in our society to transcend the domain of school, the orientation expressed by Dewey a century ago or by people like Papert and Schank in recent months becomes ever more plausible as a basis for the design of learning experiences. The constraints of formal education do not hamper the person who is designing learning opportunities for individuals in the workplace or the home.

This brief summary of thinking on natural learning leads to three key points. First, schools do not own the child’s learning. Children are continuously engaged in learning, and even though the learning which occurs in their life outside of school may be woven into their environment in ways which may make it less conspicuous than when they are sitting in a classroom with a teacher standing before them presenting some concept or information, it is learning nonetheless. Through the span of civilization schooling has been only one of the ways by which humans have learned what they needed to learn in order to function. Until quite recently (when put in the context of human civilization) the extent of the schooled population was quite limited.

Second, information technology has generated interest in natural learning and provided means to create new learning environments. While there is one cadre of developers and vendors of information technology who are intent upon developing uses of technology that fit into the existing conditions, traditions, and procedures of schools as they are, there is another and more important cadre who are attempting to make use of the technology to promote learning with less commitment to where the learning takes place or how well it conforms to expectations of the educational establishment as to its validity. This orientation emphasizes the motivational, attitudinal aspect of learning. The student may not be able to walk out of the boring class, but he or she can certainly switch off the boring multimedia program. Information technology is particularly compatible with the nonlinearity and experiential texture of natural learning.

Third, many who are inadequate learners in the school context seem to have no particular disability when they are learning in out-of-school contexts. The ability to learn is not an esoteric human characteristic; it is quite normal. The high incidence of learning pathologies in schools has much, much less to do with any organic or function disability of learners than it does with what students are told to learn and how they are told to learn it. Designers of educational materials using information technology can focus their attention on the learning requirements of the users rather than on the needs and requirements of the organizations within which the learning is supposed to take place.

THE FUTURE OF LEARNING AND SCHOOLING IN AMERICAN SOCIETY: CONCLUSIONS AND IMPLICATIONS

The 19th century was a period of institution building. It was a time of a great changes in the United States and a time when men and women believed in their power to create institutions to solve the pressing problems caused by the changes. Prisons would eliminate crime. Insane asylums would put an end to mental illness. Reformatories would abolish juvenile delinquency. Schools financed by the state would stamp out ignorance, create a literate populace, and mold upright citizens for the Republic. The state-supported system of schools would be the "melting pot" where children from diverse backgrounds would meet and be instructed in a manner which would ensure the maintenance of the "American way of life."

The reformers were successful in realizing their vision of schooling throughout the United States. They enacted the laws and policies which were required to institutionalize public schools. As a result of the work of the reformers, schools became *the* place—rather than *a* place—designated by society to transmit the cultural tradition to each successive generation. Public policy tolerated, but did not encourage, the formation of alternate approaches such as parochial or private schools. The basic features of the schools put in place by the 19th-century reformers have endured, much to the chagrin of scores of later-day reformers. The durability of the American system of schooling is a function of an architecture which was particularly harmonious with the ideological context of the times. But times have changed.

Information technology is the principal force generating the great transformation of economic, political, and social life in recent years. Information has become central to every domain of human life and pervasive in every venue of human existence. Human beings have always had the task of obtaining, integrating, and using information as a basis for their thoughts and actions, but at no point in human history has day-to-day life for the preponderance of the population put them in such proximity with the informational resources of the culture. The economic and social value of being informed was never greater than it is now and there is no reason to expect this to abate. The printing press did not turn everyone into an author, but it did substantially expand the number of such persons. Not even desktop publishing and networks will turn everyone into information producers, but we are already experiencing an explosion in the numbers of persons who are producing and publishing information, and more access to these tools can only further expand the percentage of the population who will produce as well as consume information. Within this context, schooling and learning take on a different character than has been the case in the past. The role of schooling in general and the American public school in particular are being changed.

As discussed earlier, one of the consequences of literacy was the establishment of schools as enclaves separated from the ongoing economic and social life of the community. Learning was "decontextualized" and provided in terms of generic skills or as information to be stored in one's mind for later use when the individual was again engaged in activities outside of school. The fundamental implication of an information technology culture for learning and schooling is that learning becomes "contextualized" and becomes part and parcel of daily life. This does not mean that schools will disappear, but it does mean that they will no longer have the dominant presence in society with regard to the transference of the culture from one generation to the next. Schools personnel who do not understand this new world of learning within which they live are likely to lead their own organizations into oblivion or irrelevance.

More specifically with regard to the American public school, it is becoming ever more clear that we are experiencing a deinstitutionalization of education in the sense that the public school is less and less accepted as the essential and principal instrumentality of educating American youth. While home schooling is not a mass movement, a considerable number of children are being educated in their homes. Charter schools have been established in a number of states. Television has become the dominant source of learning about the world. Millions of people are using the Internet as a means of accessing information and learning about an almost infinite variety of topics. There seem to be few people, beyond the circle of public educators, who contest the idea of establishing schools apart from the control of local educational authorities.

The belief in the power of institutions is not as prevalent among the citizens of the later part of the 20th century. Much of the rationale for the establishment of the American public school sym stemmed from the belief that a state-supported system of schooling which educated the rich, poor, immigrants and established middle class was the means to insure a common culture congenial to American political, social and economic life. The extent to which the American public school achieved this mission is a topic of debate between those who believe it did serve to bring the diverse sub-groups of American society into a cohesive entity, and those who believe it served the purposes of a white Anglo-Protestant middle class. The optimism of people in the 19th century about the power and value of institutions overstated the case, but the pessimism of the current generation about institutions probably is also overstated; nevertheless, the "melting pot," "the common school," and standardization are not themes which resonate in contemporary America. Now "choice," "diversity," and "deregulation" are the bywords.

The landscape of American education in the later part of the 20th century is looking more and more like it was in the colonial period through the early days of the Republic. The variegation which so characterized the approach to education appears much more compatible with the nature of an information society than does the uniformity and linearity of the conditions engineered by the 19th-century reformers. The parent who is concerned about his or her child's intellectual development is able to buy learning materials at the mall or through a network service. School personnel who are committed to the welfare of the young people they serve need to be comfortable working with other organizations and purveyors of learning resources as partners rather than as the agent incharge.

Most people realize that information technology needs to become part of the schools in some way. People expect to see computers in classrooms and believe that students should spend some of their time in schools working with them. School boards and parent groups have seen to it that there are computers in schools. There are few schools in the United States where one does not find computers in classrooms, media centers, or computer labs, and it is not difficult to identify teachers, here and there, who are making interesting, and in some cases, powerful instructional use of computers. Unfortunately, there are still an appreciable number of proponents of technology in the schools who seem to focus more on getting computers used in schools than they do on the educational value of how the computers are used. Success ought not be measured by how many computers there are in schools, how often they are used, or how well they can be integrated into existing curriculum content—much of which is irrelevant or antiquated. There is nothing to be gained by using information technology in the schools to become a more efficient anachronism. The danger of this is real since many proponents of technology in the schools have a 21st-century conception of technology and a 19th-century conception of knowledge and learning. The challenge is to use information technology to create in schools an environment conducive to the development of individuals who have the capability and the inclination to use the vast resources of information technology in their own continuing intellectual growth and skills expansion. Schools should become places where it is normal to see children engaged in their own learning.

Bringing schooling into an information technology culture is a much more difficult task than doing so for businesses or factories. What was required of American industry to make the changes necessary to survive in an information age was for the leaders of corporate America to understand the nature of what needed to be done and to work with others inside the organization to implement the changes. This was not an easy task, but corporate leaders did not have to get the general public to accept the fact that they would find a strikingly different environment when they walked into an automobile manufacturing plant in 1990 as contrasted with how the plant would have looked in 1950. The general public does not have detailed beliefs about what it means to be a good factory apart from the belief that a good factory turns out a good product. The general public does have beliefs (or, to use the terminology of the earlier discussion, "rational myths") pertaining to schools which are often strongly held. The beliefs about the nature of schools and schooling held by parents, citizens, and policymakers whether articulated or not set the parameters for what is perceived to be legitimate and appropriate activities in classrooms. The crux of the crisis for schools is the discordance between existent beliefs about schools and schooling and the conceptions of knowledge and learning engendered by developments in information technology. A new rational myth needs to be created.

The history of audio-visual technology in schools has established a precedent that needs to be overcome. Radio, telephones, audio tape, filmstrip projectors, slides, television, etc., were all seen as means to be used by teachers to assist them in improving teaching. A popular shibboleth is that the computer is a "tool." While computer applications are tools, the idea that computers are just means to an end is a serious misunderstanding about the extent to which information technology represents essential changes in the creation and transmission of the culture. Those who wish to determine the extent to which schools are using information technology to change more than merely the cosmetic aspects of schools need to begin by asking school personnel what they no longer do or what they have eliminated from the school because of their use of information technology. The next question is: What is happening in this school which did not, or could not have happened, in the past without the use of information technology? The least important question is: What was done in the past and is now being done in a different way because of the availability of information technology?

At the heart of the way schooling has been carried out for the past century and a half is a conception of knowledge as an historic product. In this formulation, knowledge is something which comes from the past work of scholars, scientists, and artists rather than being a work in progress. The dissemination of knowledge using print has obscured the dynamic and even disorderly nature of the process by which it is created. The school curriculum carves knowledge into subjects and arranges the content of the subjects in a sequential, hierarchical order corresponding to the grade levels. Teachers in the first grade know what math, language skills, etc., they are supposed to teach and they understand that they are not to infringe on what will be taught in second grade. The systematic processes of curriculum standardization and age grading of instruction, as well as the establishment of diploma requirements, is based on the assumption that there is a collection of facts, concepts, and skills which need to be installed into the minds of students and that this needs to be done in a orderly manner which conforms to the logic of the discipline.

Information technology shifts the conception of knowledge from something one has learned to something one uses. This is not a new way of thinking about knowledge. The great philosopher and mathematician Alfred Whitehead referred to knowledge as only something one had to learn and which had no utility for the individual as "inert knowledge." Whitehead wrote with great passion about the need for learning to have connection to the lives, interests, and contexts of the learner. "Ideas," he wrote, "which are not utilized are positively harmful. By utilizing an idea, I mean relating it to that stream, compounded of sense perceptions, feelings, hopes, desires, and of mental activities adjusting thought to thought which forms our life" (39). In Papert's terms, this is a constructionist point of view. The work of individuals such as Whitehead and Dewey make it clear that a dynamic and utilitarian conception of knowledge is not a recent understanding, but information technology elevates the need to recognize this reality because there is less benefit gained by remembering knowledge and more benefit to those who can produce it, find it, or use it.

The 19th-century reformers were inventors. They saw themselves in the tradition of the other great inventors of their day who had constructed machines to do wonderful things. The conception of schooling which they established involved the invention of a social mechanism which they believed would do what it was constructed to do with the same assurance as the other inventions which were transforming American life. Their social mechanism was a carefully crafted system which would produce an educated populace for society. System is no less a popular word in educational parlance in 1994 than it was a 150 years ago, and the term "systemic reform" is also fashionable. Yet, the analyses presented in earlier pages of this paper suggest that it is time to move beyond the system metaphor. Certainly, from a social science perspective, the concept of the school as a social system remains a useful analytic framework with which to define the key structural elements and the roles and relationships of the people who maintain the system. Yet, system, in the context of schools, brings with it much "baggage" which is dysfunctional. It keeps us linked with the 19th-century reformers' belief that it was possible to create a system of schools within which a proper arrangement of the elements of the system and an effective pedagogy could ensure the accomplishment of the expected instructional objectives. There is nothing to be served by continuing a quest for the Magic Fountain of Schooling, since there is none to be found. The time has come to abandon the idea that it is possible to create a social mechanism which can act on the students who are in it in ways which ensure the desired outcome.

Efforts which approach the task of school reform from the perspective of the design of environments offer a better footing for an attack on the problem than those which set out to figure out how to substitute one system for another. More of the mentality of the architect is needed to design environments which incline those who share these places to create learning communities which take full advantage of personal productivity and networking resources. Ironically, the surest way to increase the likelihood of desired outcomes may be to concentrate on the design of environments which make desired processes more likely. Thinking about schools in this way requires less compulsiveness with regard to content objectives and more focus on the factors which support learning activities. Such environments would be places which no longer fought the losing battle to enforce an unnatural form of learning. Touting this orientation would be an act of futility (as it was for Dewey and Whitehead) were it not for the fact that there are serious and increasing efforts to develop learning processes which understand the centrality of the learners' own interest and involvement in their learning and which respect the natural processes of learning. These efforts are centered mainly outside of formal education and are led by those who are interested in reaching the market for learning in the home and the private sector. Those concerned about learning for children in our society should also participate in the exploration of new forms of learning environments and resources.

In the 1950s and 1960s, in the era of the ascendancy of broadcast technology, there was fear of an informational monolith as three powerful television networks emerged and as fewer cities had more than one newspaper. In the 1990s, in the era of network technology, these fears no longer prevail. Developments in the use of information technology over the next years provide a growing number of new educational alternatives. There is no doubt that there will be great progress in the next decade in the development of learning resources which make use of the capabilities of the technology. Commercial networks such as Prodigy and America On-Line carry educational offerings for young children. They will be joined by other networks bringing learning opportunities wherever there are children. The quality of the offerings will vary. Some, possibly many, will be poor, but there are certain to be very appealing and effective resources as well. With increasing capability in networks and with the development of small, inexpensive devices with multimedia capability, designers of learning resources will have the resources they need to develop attractive and effective learning environments. The federal government, states, and the private sector need to work together to support the development of network resources for children and youth. Children of reasonably affluent parents will have access to network resources, but the concerns, frequently addressed, of a bifurcated society based on information access are real. There is no one solution to the problem of the gap between the rich and the poor with regard to access to information, but public policy needs to be continuously attentive and responsive to this problem.

It is impossible to conceive of how to bring schools into the information age without a very substantial expansion of equipment available to learners. Computer labs or the availability of a few machines in classrooms are hardly adequate. Many schools have had to struggle to provide a relatively small amount of equipment, and they have been provided little funding for applications software, support, maintenance, training, or upgrades. Unless one expects very significant new money to come to school districts (an expectation which few hold), the money needed to make information technology a dominant element in the lives of children in classrooms is not available given existing conditions in school districts. Special millage or bonding initiatives to purchase hardware represents a way for schools to take a significant step forward, but special funding does not address the issue of maintaining information technology as a major and continuing element in the operation of the schools.

The option of having a sufficient deployment of information technology so that it becomes mainstream in schools while maintaining everything else schools currently fund is unrealistic. The funding for substantial increases in technology on an ongoing basis can only be accomplished by changing the way the existing funds are being spent in a substantial way. This may also include labor costs. The painful reality faced by other organizations which have moved to make information technology a major aspect of how they function is that the technology is purchased with the money recovered from reduced labor costs. Any changes in the way in which school districts spend their money will be sharply contested by teacher unions and, in many cases, by parents and other residents of the district. If public schools do not find ways to move in this direction they will find themselves in competition with other educational entities such as private schools, charter schools, educational networks, and the other new organizations which provide technology-based educational services for children. The restructuring of the public schools and especially the restructuring which entails the effective use of information technology can only occur if school leaders have the courage and political skill to accomplish the task of fiscal restructuring.

The availability of applications software with regard to learning opportunities for children and young people is a mixed situation. There are two kinds of applications which children and youth need to encounter. One type is the various productivity and information utility applications such as word processing, quantitative modeling, bibliographic and informational data bases. Of course, the quality of these applications continues to improve and children and young people need to have access to them as a conventional element in their education. The only problem which needs to be solved with regard to this type of application is seeing to it that children and youth have access to the same tools as those being used in the world beyond the schools and not antiquated applications.

The other type of applications pertains to those programs which are devised as learning resources for children and youth. Most of the programs which are marketed as learning resources for children and youth are of poor quality, even when judged on their own terms as quite conventional drill-and-practice or tutorial programs. Even more problematic is the situation with regard to innovative materials which begin to exploit the design opportunities provided by equipment of increasing capability. Private as well as public funds need to be provided to support the development of applications which furnish concrete and usable versions of the type of rich learning environments discussed earlier.

The creation of colleges of education was a consequence of the school reform movement of the last century. The perceived value of colleges of education was contentious at the point teacher training entered the university and has remained so to the present. The radical changes which information technology is generating in American education creates a need and opportunity for colleges of education. Within colleges of education through-out the United States there are individual faculty members who are involved in efforts to make new technology improve the lives of children and youth. Unfortunately, there are fewer examples of colleges of education which have grasped the significance of information technology for how they are to function and for the viability of their future.

There are two elements to the formation of a future for colleges of education. The first is that colleges of education need to be involved in the development and use of information technology as it improves the educational opportunities for children in the broad array of venues wherein this will occur. For the most part, colleges of education have been "colleges of schooling." The economics and ideology of the past have forged a tight connection between them and schooling, which was usually public schooling. The value of colleges of education will be even more suspect if they attempt to hold to an orientation to education which is less and less an accurate depiction of reality. A misplaced sense of loyalty to formal education will not even serve the needs of schools since schools are faced with the need to function within a new educational world. Colleges of education need to be seen as places where knowledge and skills reside to assist schools in making effective use of information technology. If colleges of education are "on the sideline" on the unfolding of informational technology in teaching and learning, then the future of colleges of education may be increasingly tenuous.

The second element pertains to the long-standing complaint about the disconnection between the training which occurs in colleges of education and the realities of life and learning in the places where teachers and other educational personnel work. Information technology provides a basis for a reconstruction of teacher education. There are obvious but not fully realized implications of the use of networking as a means of establishing linkage between colleges of education and schools and other places where education occurs. Also, colleges of education which produce credible and useful research or development products can make use of information linkages to enable their products to be used.

A new era of the human condition has begun. This transformation will bring with it problems and opportunities. No area of human existence will be more affected than the processes of education. The question of how well the resources of information technology will be used to improve the lives of our children is as yet unanswered. The responsibility to begin the construction of the answer to this question falls upon this generation.

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Appendix B Learning and Teaching in 2004: The BIG DIG

B

by

Beverly Hunter and Bruce Goldberg

Bolt Beranek and Newman

When we consider the confluence of trends and pace of change in the economy, society, and technology, it is relatively easy to envision systems of schooling, learning, and teaching a decade hence that are very different from those of the past 100 years. It is not clear, however, whether all current educational reform movements are consonant with such a vision.

Our vision of teaching and learning 10 years hence is informed by current and past experiences of technology-using innovators within education, combined with trends outside of the educational system that drive the requirements and opportunities for learning and teaching. One set of external drivers includes global and national trends in economy and demographics (31,32,79). Another set of external drivers includes the rapidly changing information technologies and information infrastructure (11). These changes in the larger society are imposing requirements for change in the skills, knowledge, and learning capabilities of citizens (17, 78, 83). Consonant with the requirements is the trend within education toward constructivist approaches to learning and teaching (65, 80).

Nearly every element of our future vision exists today for some people at some times and in some places. What makes our vision different is the pervasive extent of participation and the seamless interaction of the human, institutional, and technological components. In reality, the shape this convergence of trends takes will be the result of political leadership and policy decisions over this coming decade.

A general theme of our vision is that learning, teaching, and schooling all will have a closer relationship and interaction with people, places and knowledge outside of schools than has been typical in the past 100 years or so (103). The "learners" and the "teachers" are people of all ages, in all walks of life (17, 40). In this vision, every person considers himself both a learner and a teacher. Some people will play a teaching role only part of the time, while others will be employed as professional teachers.

Numerous reports from stakeholders as varied as mathematics teachers and industrial leaders have directed our attention to various facets of this general theme. Most recently, for example, the U.S. Congress, in the School to Work Opportunities Act of 1994, addressed many of the cultural, economic, technological and cognitive factors in its findings:

- three-fourths of high school students in the U.S. enter the workforce without baccalaureate degrees, and many do not possess the academic and entry-level occupational skills necessary to succeed in the changing U.S. workplace;
- a substantial number of youths in the U.S., students of diverse racial, ethnic, and cultural backgrounds, students with disabilities and especially disadvantaged students, do not complete high school;
- the workplace in the U.S. is changing in response to heightened international competition and new technologies, and such forces, which are ultimately beneficial to the nation, are shrinking the demand for and undermining the earning power of unskilled labor;
- the U.S. lacks a comprehensive and coherent system to help its youths acquire the knowledge, skills, abilities, and information about and access to the labor market necessary to make an effective transition from school to career-oriented work or to further education and training;
- students in the U.S. can achieve high academic and occupational standards, and may learn better and retain more when the students learn in context, rather than in the abstract; and
- the work-based learning approach, which is modeled after the time-honored apprenticeship concept, integrates theoretical instruction with structured on-the-job training. This approach, combined with school-based learning, can be very effective in engaging student interest, enhancing skill acquisition, developing positive work attitudes, and preparing youths for high-skill, high-wage careers.

In an increasingly globalized environment, both public and private enterprise must be agile to deal with rapid changes in markets, customer and client, and community requirements. Innovation requires rapid adaptability. Agility must be achieved by a combination of technological and organizational changes. One important change is the delegation of substantial autonomy to reconfigurable, relatively autonomous teams of workers (46). Work reorganization and new technologies propel employees and citizens to take more responsibility, cooperate more with each other, understand their roles in the production system, and act on that knowledge (17, 40, 79). Rather than the predetermined curriculum sequence of the industrial era, people need to learn new subjects and skills at the time they are needed on the job or in civic life.

VIGNETTE: "THE BIG DIG"

We illustrate key elements of our vision through a vignette that takes place in the year 2004 in metropolitan Boston. The Big Dig is a real project. Boston's Big Dig—or Central Artery Tunnel (CAT) project, as it is officially known—is the largest single civil construction project ever undertaken in the United States. A 10-year, $7.7-billion effort, it will include depression of the Central Artery an elevated highway through the heart of Boston construction of a new system of off and on ramps, and the construction of a third tunnel under Boston Harbor. Today, in 1994, the project is scheduled for completion by the year 2004.

The "Big Dig" educational vignette presumes that in the mid-1990s, educators began to build a significant body of exemplary learning resources and activities based upon the Central Artery Tunnel project. Through existing and emerging educational reforms, telecommunications networks, and the evolving National Information Infrastructure (NII), an educational collaborative of teachers and learners of all ages was built.

Vignette Prologue

It's a beautiful spring morning in April 2004. Ten years ago, Massachusetts began its evolutionary effort to restructure the entire way it organized, delivered, and financed education. It's also a special day in Mercedes Banzon's life.

Crossing the street to the Boston Museum of Science, Mercedes reflects on some of the changes she's seen and undergone over the past 10 years. She smiles and shakes her head. Ten years ago, she was "just a teacher"—a self-disparaging phrase she often replied with when asked what she did for a living. Nowadays, in 2004, almost every job involves at least some teaching and a lot of learning. Every industry and public organization now routinely employs teachers. Mercedes recalls one of the most revolutionary aspects of Massachusetts' belief statements of the Goals for the Next Century document: "In the world of the year 2000, there will no longer be possible or desirable the radical separation of civic life, work and continuing education. Education must cease to be an institution, and become instead, a way of life."

Mercedes is now proud to proclaim that she is an "educator." The transformation telescoped in her mind. Ten years ago, she volunteered on a Goals 2000 school/community committee in Dorchester. Today is her first day as Chief Education Officer for the Boston Metropolitan Education Region (BMER). Her visit to the Boston Science Museum will help remind her how all the changes in education over the past ten years have taken root in the lives of students, teachers, parent and community members—in short, everyone.

Mercedes remembers that 10 years ago, teachers and students spent all their time in "school buildings," sealed away from the vital life of learning and information their communities offered. On the other hand, the majority of adults were not a part of the formal educational system and thus had little opportunity to participate in organized learning activities. Advances in communications technology had helped break down some of the walls. That was what first got Mercedes going. As technology coordinator in her school, she worked on a project initiated by the local phone company to start the first school voicemail system in the Boston area. The system enabled parents to more easily communicate with their children's teachers. The next step was a logical one- connecting this phone system with computer dial-up access. At that point, parents could use their computers to access local social service agencies, discover employment possibilities, and enhance their own education. In the late 1990s, businesses in Massachusetts had begun donating and loaning computers to workers and parents as part of a major " lifelong learning" initiative that evolved out of a convergence of federal and state programs. These programs included: Goals 2000, statue and urban systemic initiatives, enterprise zones, and a bipartisan Massachusetts industrial competitiveness effort to make the state more attractive to business and industry.

The creation of the Boston Metropolitan Education Region (BMER) was an institutional outgrowth of these initiatives. Many school system jurisdictions found common ground with the "lifelong learning" initiative proposed by industry-education partnerships and coalitions in the area. The BMER was funded by a combination of these federal, state, industry, and local funds. It is highly dependent upon the CWEIS (Community Wide Education and Information Services) formed in 1994 to take advantage of computer networking in the region.

Mercedes recalls that as its first pilot project, BMER issued a Request for Proposal to students, teachers and community members inviting them to design a nine-week project that would engage all the participants in collaborative projects without regard to the political boundaries of their school districts. Mercedes organized a group of teachers, parents, community center leaders and professionals from health and human services. This group developed a winning proposal and conducted a successful community-wide educational *project called "Using Your Brain," that took advantage of many resources across the area including television, radio, computer networks, and newspapers. This was one of several projects that achieved city-wide citizen awareness of the educational value of many different institutions and groups.*

The Tunnel Team

Mercedes walks through the front door of the Boston Science Museum and sees the brightly colored sign "To the Dig" directing her down the hallway on the left.

Fourteen-year-old Azikwe Jackson-Hu has also arrived early at the Boston Museum of Science this Monday morning. There's a special all-day work session with his Tunnel Team. By 9 a.m. about 30 people have arrived.

The session facilitator is Elaine Corzini, a teacher from the Mather school in Boston. She introduces the goals for today's work—preparing for their Tunnel Team exhibition at Big Dig Week to be held next month. Several thousand visitors are expected at this Boston-wide event. It will also be viewed by many more people through television and computer networks.

To set a high standard and expectations for the Tunnel Team's exhibit, Elaine shows a brief video of last year's exhibition. In it, one team had developed a mathematically interesting analysis of hourly carbon monoxide and temperature readings at several points in the tunnel, over an eight-year period. The large poster display of their insightful charts and graphs had resulted in extensive publicity and, eventually, in improvements being made in the tunnel ventilation systems.

Elaine reminds the group that this exhibition is an important opportunity to get feedback and evaluation for their work on the tunnel project. They need to make careful plans to take advantage of this opportunity to assess their progress in learning.

Although this project team has been working together for many weeks, there are as usual some newcomers at this session. They begin with introductions:

- 20 children, ranging in age from about 10 to 16, who attend three different schools in Boston, Charleston, and Somerville;
- an undergraduate teacher-in-preparation from a local college;
- a graduate student in engineering from MIT;
- an engineer from Bechtel, the Big Dig contractor, and parent of one of the children;
- another teacher from Elaine's school;
- a member of the exhibit staff of the Boston Science Museum;
- a staff member from the Metro Boston Transit Authority (MBTA);
- a faculty member and student from Roxbury Community College;
- a member of the Urban District Assessment Consortium, who specializes in student assessment; and
- also present via video conference are teachers and students from four schools in the Boston area, and Azikwe's mother who is on travel at her company's office in another city.

Because Azikwe's mother has to leave the meeting by 10 a.m., it is agreed that they will begin with the demonstration. Azikwe is impatiently waiting to get started. His mother says,

"Azikwe and I would like to show you some parts of the tunnel simulation and control system that I have been working with as an engineer for the CivTech company. We are subcontractors to Bechtel for tunnel monitoring and maintenance. By the way, Calvin is our contract monitor—Hi, Calvin. Calvin might explain to you later how we managed, after three years of fighting our bureaucracies, to get permission to make this tunnel simulation software publicly available on the network."

While his mother is talking, Azikwe has been operating the computer, getting the tunnel simulation program up on the large screen in the front of the room next to the video conference screen. The teachers and students at the remote locations use a shared workspace tool on their computers so they can see the same computer screen that Azikwe is demonstrating.

She continues, “Azikwe, if you will put the main screen up there, I’ll explain the four main components of this system. Then we’ll take a look at the structural design part that I use in my work.”

About 20 minutes into the demonstration, one of the children asks, “Mrs. Hu, can I ask you a question? How come your tunnel looks really different from *our* tunnel simulation? Isn’t this the same tunnel? The only thing that looks the same to me is that the tunnel is made of 300-foot-long tubes.”

Azikwe’s mother replies, “Meera, you ask an excellent question. Azikwe has shown me your team’s tunnel simulation many times, and I know that these programs do look very different from each other. This is because we have different purposes, and are using different software. Your team has been building your tunnel simulation to help you learn and understand and share your understanding of the design principles, and the mathematics and physics needed to understand the design. My program, on the other hand, is used by professional engineers responsible for monitoring and maintenance. So we engineers need different information than you do. Azikwe, would you show the cross-section view again? Notice, for example, that we have much more detail about the electrical system in this cross-section than you would need in your simulation.”

Several children, and adults, are now waving their hands for attention. Andy preempts the others. “Mrs. Hu, I have an idea for our exhibition. We could have two screens side by side where we show the differences between yours and our simulation.”

Mrs. Hu starts to reply but Jewelle interrupts, “But we can’t do that! Her program is too complicated! I don’t even know what any of those icons mean up there.” She runs over to the screen and points to the icon menu across the bottom.

The community college professor speaks up, “I have some students in my classes who are technicians with the transit authority. They could really sink their teeth into this program. Is it okay for me to introduce it to them?”

Mrs. Hu says, “I think that that’ll be okay...I’m sorry, I have to leave for another meeting right now. I’m sure Azikwe will tell me tonight what you decided. If you do decide to work on this, there is a new engineer here on our staff who is just learning this system. He might volunteer to help you learn along with him. Bye, all. See you at the airport at six tonight, Azikwe.”

The session suddenly becomes chaotic, exploding with a dozen simultaneous conversations. The teachers and students on the video screen look confused, since they can’t understand what anyone is saying. Mrs. Corzini tries to get more discipline into this creative firestorm.

“Let’s capture all these ideas in the collaborative notebook, right now,” she says. “Make groups of four or five people and enter your ideas into the notebook file Tunnel Session Nine.”

About eight small groups form spontaneously, entering their ideas into their notebook computers at the work tables. One of the students gets the collaborative software up on the large screen so everyone can see the emerging comments. Mercedes notices one small group that includes only younger children and asks Lew Girshalt from the MBTA and Ana Julia, a teenager from Somerville, to join them.

The teachers and students at the remote sites join in from their own computers, so everyone can share in the swirl of ideas, exclamations, arguments, sketches.

Here is a sampling of the comments the groups are entering into the collaborative notebook:

“What about our traffic data? We wanted to make a game where people have to correlate traffic statistics with days and times.”

“Mrs. Hu’s program is too complicated for the younger kids.

“We could connect her tunnel program to our GIS maps of the neighborhood.”

“I could help the students ferret out assumptions in Mrs. Hu’s model about the structural properties of the tubes and compare it to the one they’ve been using.”

"We were going to videotape the inside of the tunnel and show how to image process a comparison with our simulation."

"We don't have enough time to learn her program before the exhibition. And besides, Azikwe's just showing off."

"Does anyone realize that that system cost the taxpayers two million dollars to develop?"

"That program will not demo well at a public exhibit. The screens are too busy and complicated, the user interface is arcane, we'd need a full-time engineer to handle the booth, who could explain it?"

"We wanted to show the hypermedia we made, where we took that old Big Dig video from 1994 and showed how things really are now, and all the mistakes they made back then."

"We built a model of traffic congestion, and compared the behavior of our simulated traffic jams to real traffic jams in the tunnel. We want to make an exhibit of our program."

Mercedes observes with pride the skills, knowledge, creativity and insight reflected in these spontaneous comments. She walks from group to group, observing the contributions being made by different members of the team. She reflects upon those early attempts at project work 10 years ago. So many of the prerequisite skills-both so-called "basic" as well as metacognitive skills—were simply not present back then, in either teachers or students, so project work was painfully slow and often unproductive. Attention to "basic" skills came first. Clear and concise formulations of what students should know and be able to do-standards—were combined with strong strategies for implementing these ideas within school settings. This prompted more complex assessments and enabled teachers to tie instruction to the diverse needs of their students. Now, even the youngest member of this team has had several years of experience and training in teamwork, investigation, observation, analysis, synthesis, and communication. Even the oldest adult had by now several years' experience in using many computer-based tools including those they used for writing, multimedia creation, data storage and analysis, modeling, communication and collaboration, and many specialized tools for their particular work and pleasure. In 1996, the BMER had recommended a common core suite of tools, and had taken steps to make the software available at very low cost across the area, in all community centers, schools, libraries, homes, government offices. This action was the landmark event that enabled the rapid development of fluency in computer use and information literacy among most people.

After lunch, Elaine facilitates as the group discusses the goals for the exhibit. On the large screen she points one by one to each of the comments made earlier in the collaborative notebook. As the group discusses the merits of each of those ideas, they record these additional considerations.

As Mercedes sits back and watches Elaine's skillful facilitation and recording of the group's discussion, she recalls the BMER meeting four years before when the very contentious issue of scheduling had come to a head in the BMER. It had been extremely frustrating to try to conduct city-wide learning activities that were constantly competing with the rigid class schedules of the separate schools. The separate schools were also at a point of crisis about scheduling because they also were attempting to conduct interdisciplinary project-based learning activities that could not function in the 45-minute class periods. It was at that meeting, while they were recording their discussion in the BMER collaboratory notebook, that they realized the technology they were using could free them from some of the time constraints of their school traditions. Nearly everyone—teachers, students, administrators, many parents—had become fluent in using project databases, collaboratory notebook, videoconferencing, project management tools, people directories. Thus it was now thinkable for people to participate in project teams without having to be physically present at all face-to-face meetings. If everyone would take responsibility to ensure that all project discussions, decisions, materials and products were carefully documented, they could free themselves from some of the tyranny of sched-

ules. So, for example, at today's Tunnel Team workshop only 40 of the 100 members of the team are physically present, another 40 are present via video conference, and the others would have to use the electronic recording to participate vicariously at a time convenient to them. Hence, Elaine's careful attention to the recording of all discussion here at the workshop.

The group decides on four main themes for their exhibition, then divide into four smaller groups to hammer out a plan of work for each of the parts. Mercedes and the other teachers each work with one of the groups. Mercedes' main concern is that each member of the team make a contribution to the exhibition, and that the evaluation plan addresses at least one of the learning goals of each team member. She helps the group address these issues systematically by referring to the electronic records of their learning development plans and the BMER assessment guides.

The experts from MIT, Bechtel, the Transit Authority, and the Science Museum rotate among the groups, serving in their accustomed consulting roles. They are all volunteering their time and expertise for different reasons. The MIT engineer is focusing her graduate studies on new methods of designing supports for underground structures. She is gaining valuable background knowledge through her work with various Big Dig educational teams. The Bechtel engineer, rather than opting for early retirement, has accepted as one of his new job responsibilities the management of the Big Dig education programs. He has been invaluable in helping the team locate data, videos, software, and other historical records of the CAT project's 10-year history. As lead contractor for the CAT, Bechtel also oversees a major portion of the designated educational fund. The Transit Authority technician is working on the Tunnel Team as part of his continuing education program, and is receiving community college credit for this project. All government employees are expected to spend 5 percent of their time in educational activities. While his own learning objectives are in the area of data analysis techniques, he has also been a lively mentor for the children, fascinating them with stories of his work life underground in the tunnel. The Science Museum exhibit designer is working with the tunnel team as part of her official work duties, as the museum is an educational contractor to the CAT project and is the main organizer of the Big Dig Week.

The groups put their draft plans and sketches of the exhibit booth in their Tunnel Team workspace on the network, so that everyone on the team—parents, teachers, students, and other community members—can access and work on the plan.

One of the teachers, the student assessment specialist, and one of the children form a group to review and formalize the evaluation plans. They begin by locating the assessment archives from last years' Tunnel Team exhibitions. They see there were some complaints from parents last year that the evaluators had too narrow a focus and missed some important evidence of the team's creativity and communication skills. They decide to avoid that problem by having two levels of evaluation of the exhibition. They call the two levels "Quick" and "Deep." The "Quick" evaluations will be made by interviewing visitors to the exhibition, who would have unpredictable kinds of backgrounds, skills, and interests but who would represent a wide range of viewpoints. The "Deep" evaluations will be made by a panel of 10 people chosen from the CWEIS school communities' database of teachers and expert reviewers.

In creating the evaluation plan, the group makes links in the database to the individual Tunnel Team students' personal development plans, the Tunnel Team's educational goals, and the emerging exhibit component groups' plans. From these sources, they create packets of background information and draft assessment assignments tailored for each of the 10 panelists. Each panelist is asked to evaluate particular dimensions of the exhibition, depending on their specialty areas—learning, basic competence, communications and collaboration, personal management, information management, mathematics, engineering, inquiry methods, etc. They compose electronic mail messages to the panelists, inviting them to participate, providing pointers to their packets, and requesting a videoconference three days hence to discuss the plan. The student member of the evaluation team takes on the responsibility to coordinate with the panelists and keep all team members informed of schedules and progress.

Just as they are about to finish their work for the day, a group of students and a teacher from Somerville High School appears on the large video screen. "Can we talk about this assessment plan?" they ask.

"Yes!"

The Somerville teacher explains, "We have been reading your draft evaluation plan for the exhibition, and the students have a concern about it. They've spent a lot of time the past few weeks learning how to develop this tunnel simulation, learning how to use the simulation authoring tools, and they fear your assessment instructions to the panelists do not reflect this."

The assessment specialist replies, "I'm not sure I understand you...aren't the students using the same simulation program that was used by last year's Tunnel Team?"

"No, that's our point. When we started this year's Tunnel Team, some of the students had already learned how to use SimMaker, and they wanted to create their own simulation. Everyone agreed, but this made the project much more challenging than last year's. Some people have been developing some very important skills in modeling and in mathematics that don't seem to be reflected in this evaluation plan."

"Would you then please revise the assessment assignments, and be sure to include a note that you have provided this input to the plan?"

"Sure. The kids and I will work on this tomorrow morning. It will be a very appropriate activity for our modeling seminar, and more interesting than the exercises we scheduled to do anyhow. When the students reflect on how much they have learned, I think they'll be surprised."

By 4:30, nearly everyone has left after a productive and exhausting day. Mercedes and Elaine stay a few minutes to exchange some of their observations and concerns.

"Today's session was productive, but I wish we'd been able to hold it three weeks ago as we had originally planned," Elaine says. " I just don't see how we are going to get everything done in time for Big Dig Week."

"I know," Mercedes agrees. "Until today's meeting, I didn't realize just how much incredibly rich activity had been taking place in the Tunnel Team this year. These students have enough material for many high-quality exhibitions. I've been hearing reports of similar progress from other BMER project groups, like the Harbor Ecology team and the CAT Economics group."

"I'd like to hear more about those groups."

"Next week, WBGH airs on national PBS a story about the work of the children, teachers and parents on the ecology of the harbor around the tunnel. A substantial amount of the material used in this television show is based on data, videos, and writings of the students themselves. As follow-up to the PBS story, students in Boston will take people around the world on a vicarious field trip through their simulated tunnel and neighborhood, using video archives from the past six years."

"What was that you were saying about the CAT Economics group?"

"You might remember that for several years, in a social studies course called "Building Consensus," students from several Boston communities have been interviewing their parents and local business people to learn first-hand how the project has affected their businesses and how they participated in the Big Dig decisionmaking processes back in the mid-1990s. Today, students are posting on the CWEIS Big Dig forum the results of their interviews with Haymarket pushcart vendors. Their advisor helps them locate a similar set of interviews with Haymarket business people conducted by Globe reporters in 1995, and asks the students to identify, describe and explain differences between their methods and findings and that earlier study.

"Some high school seniors who worked a survey of Haymarket vendors back when they were freshmen are writing their senior project on the economics of the Big Dig. Because they have been working with Big Dig concepts and data for several years, and because they have personal knowledge of many aspects of this project in which they've grown up, it's possible for them to tackle this very complex problem. They've identified all direct sources of funding of the Big Dig construction itself—federal, state, and local governments and private funds—over the past 15 years, and also identified several alternative economic models to use in describing effects on jobs, businesses, industry, individuals and communities. Their work will be evaluated by a team composed of teachers, economists, academic standards specialists, and students, as part of their qualifications for graduation."

"Well, they do have a couple of Harvard and MIT students working on it with them. In fact, I was talking with a world-renown economics professor at Harvard who says this is a precedent-setting analysis of such a large public works project's economics."

"Like the student journalists who stirred up all the controversy last week with their investigation of some politically questionable financial records of the Big Dig?" Elaine grins.

"Adolescents have been stirring up trouble for years about the Big Dig. Students across the city have been publishing a weekly newsletter, *Big Digger,* on the CWEIS. The students' material has contributed to many stories in the Boston Globe and local community newspapers."

The Science Museum staffer reappears, listening to their stories and adding one of his favorites:

"A history class has been studying native American artifacts collected from the Harbor Islands prior to the building of the Harbor Tunnel. They digitized many of the artifacts such as the 3,000-year-old spearhead found at Spectacle Island, and have put these on the CWEIS Web with the guidance of a graduate student archaeologist at a local university. They've been corresponding on-line with several native American historians and students to discuss the dating and interpretation of these artifacts."

"Did you ever imagine the day would come when we would be complaining because our students are doing so well?" Elaine smiled as she said it. "But it's true. We're seeing an explosion in productivity. The ratio of adults to children in the projects keeps growing, now that all the government agencies, social services, and businesses have begun actively encouraging or requiring their clients and employees to show continuing education progress, and the BMER started awarding formal credit for participating in its projects. Now that so many more adults are involved in children's learning, it is not just a few privileged students who get to engage in complex, exciting projects. Nearly every child in the Boston area is spending at least two hours a day in these challenging activities. Many children spend as much as six or seven hours a day because they work from their neighborhoods and homes as well as school. Most rewarding to me is to see the teenagers who now get recognition for their energy, creativity and focus, instead of being thought of as troublemakers."

"Well, there was that gang that built a videogame in which the winner blows up the tunnel," Mercedes sighs, "but two of them got hired away by a videogame company so I guess they're out of our hair for awhile."

A Few Weeks Later . . .

The Tunnel Team teachers, in a videoconference, discuss the evaluation results from the Big Dig exhibition. They are concerned about some weaknesses in their students' mathematical understanding as reflected in their project work.

One member of the teaching team suggests these students need more work with combinatorial properties of patterns and representations of three-dimensional solids.

Another teacher searches the Big Dig learners' task bank. The Big Dig educational task bank has been accumulating over the past nine years, with contributions from teachers, students, parents, professionals in the community, and various educators. The task bank began in 1995 with a grant to the Metropolitan Boston Community-Wide Education and Information Services (CWEIS) for a multi-channel, multimedia educational project. This project launched the educational Big Dig collaborative that has been growing since that time.

She locates three activities that might be helpful. The others look at the activity descriptions on their own computer screens. These are geometry tutorials developed back in the 1980s and they don't take advantage of the dynamic three-dimensional solid modeling tools the students are already accustomed to using. The teachers are not entirely happy with these tutorials, although they agree they are worth trying.

One teacher tunes her network agent to "geometry education," and finds the Geometry Forum at Swarthmore. Live at the Forum at the moment is a small group of high school teachers talking with a researcher in math education.

"Excuse me, may we interrupt for just a few minutes to ask for some advice?" (She types instead of using voice, so she will make a less obtrusive interruption of their apparently informal meeting.)

"Sure. What's up?" they say, using voice.

She introduces herself and her team, and explains their situation.

"Could you point us to a sample of the students' work, and the panel critiques?"

"Sure. Tell your navigator to go to tunnelteam.bigdig.cweis.boston.ma.us."

"OK. We'll take a look later this afternoon and leave you some notes there. I recall a group in the

Bay Area of San Francisco was working on something similar with one of the technology labs. We'll check it out for you."

"Thanks! Talk to you soon."

"You're welcome. I assume we may point some other educators to your project?"

"Yes. Our fair use policies are described at the CWEIS home page."

"Thanks. Bye."

The third member of the teaching team, an applied mathematician at the civil engineering firm working for the city, agrees to follow up with the Geometry Forum advice, introduce the Tunnel Team to the new activities, and monitor the students' progress with the activities over the next two weeks.

The Big Dig educational task bank has evolved and accumulated over 10 years. It is a very rich resource, but the quality and appropriateness of the materials for any given situation or learner's needs is variable. Individual teachers often have difficulty identifying task materials suitable for a particular learner or group. For instance, spatial sense, geometry, and visual representations have been focus of renewal in mathematics curriculum since the 1989 publication of the NCTM Standards (64, 90). But even in 2004 it is still difficult to find appropriate learning materials in this area, especially in an interdisciplinary context.

One of the many issues surrounding the task bank—and all materials in the Big Dig distributed information base, including student work—has been the changing rules and customs about intellectual property rights for these materials. Hence the "fair use" policies are explicitly explained in the CWEIS, and each task package includes information about the developers, evaluators, users, and fair compensation policy.

Same Time, at the Community Learning Center

Mrs. Maturana, a recent immigrant from Calí, Colombia, has learned from her daughter that there are jobs available on the Big Dig project. At the community learning center where she is taking lessons in English as a second language, she learns about the jobs databank that is provided by CWEIS. High school students in information systems apprenticeships have been working with the metropolitan Central Artery Tunnel administration to keep the job bank updated. A Spanish-speaking volunteer at the center explains to Mrs. Maturana the different programs available.

Mrs. Maturana is interested to learn more about this, both so she might find a job, and because she would like her high-school age daughter to have such a learning experience.

The volunteer doesn't really know much more about the high school apprenticeships, so she tunes the CWEIS navigator to the CAT administration building. The office building is also a project-based center for high school youth in a school-to-work program for a certain number of hours a day to work on information systems projects. A receptionist appears not to be very busy, so the volunteer asks in voice, “Hello, we’re over here at the Somerville Community Learning Center. Can you tell us about the CAT high school information system apprentices?”

“Oh yes, there are always at least a couple of them around, day or night. I’ll see if I can get one of them to talk to you.”

“Wait. Can you find someone who speaks Spanish?”

“Sure, I think so. Hold on.”

A few seconds later a teen-ager appears on their screen. In Spanish she describes the apprenticeships and the jobs bank.

The metropolitan planning authority, of which the CAT is one part, is working on revitalizing the inner city. It has Big Dig Jobs opportunities created to permit learning to go on simultaneously with the work. So, for example, you might get an unskilled labor job to begin with, and take classes to increase the skills you want to develop. There are opportunities to use these new skills so that you will not be doing menial work without a future prospects once the CAT project is completed.

Mrs. Maturana, still trying to understand all this news about her new city, asks how such a system of working and learning is possible. Who pays for it?

The student explains that his is a joint effort of the city government, private industry, and educational institutions. Industrial firms benefit as well as government agencies. For example, there are some job openings at the plant where concrete sections are made for the underground highway. The workers there are learning a new concrete mold manufacturing technique from the online manufacturers extension service (61).

“Well, Sra. Maturana,” the teenager ends,” I think that you and your daughter Ana Julia should make an appointment to come down to the CAT building. I can help Ana Julia apply for an internship here, while you look for jobs in the database. Let’s find a time next week-I’m here Monday and Wednesday afternoons !”

TEACHING AND LEARNING: UNDERNEATH THE BIG DIG

The Big Dig vignette weaves together many strands of institutional change, learning activities, teacher roles, and technology applications. All these components currently exist in some form in 1994, although they are not yet integrated as widely and deeply into a community as the Big Dig vignette portrays.

Why the Big Dig theme? We use this organizing framework because it helps us think in a concrete way about several elements of reform advocated for education. One set of concepts that can help tie these elements together is embedded in the term “authentic.”

The Meaning of “Authentic”

The notion of authentic instruction is related to our understanding of how people learn. People bring their prior experience and concepts to new situations, and construct their knowledge out of their interaction with the world (4, 12, 65, 80, 91, 102). A community-based scenario such as the Big Dig spotlights the interaction of everyday life and learning. The Big Dig as an educational theme and context, draws on individual and group experiences at home, in their neighborhoods, from their newspapers and television, so that the construction of new knowledge flows naturally from the everyday realities of life.

The CAT project is a very large endeavor affecting in different ways the lives of nearly every person in a metropolitan area. Hence as a theme and context for learning and teaching, it draws upon the real-world experiences of children, professionals, parents, workers and politicians across the diverse neighborhoods of a city. It acknowledges the great diversity of people, and the fact that they bring different backgrounds and experiences to a learning situation(10). Such an emphasis and respect for diversity is a key step to equitable educational opportunity in our increasingly multicultural society. A city-wide context for learning is not the only possible approach to creating a culture of lifelong learning that offers universal and equitable opportunity for everyone. One could, for example, focus on a global context, or on a virtual community of people who share a common interest and background irrespective of their geographic location (11, 82).

Authentic means working on projects and problems of intrinsic interest to the learner or a group of learners, rather than learning what everyone else of the same age is expected to learn at the time; working collaboratively with peers and mentors; closer relationships between people inside schools and outside in the "real world." This cannot be accomplished unless there is a sustained motivation and interest on the part of all the people involved. The CAT project is so large it affects nearly everyone's life. It is multidimensional and of long duration (decades) so that it provides a sustained motivating context. The CAT project involves local, state and national politics, history, ecology, finance, engineering, mathematics, science, social science, journalism, media, business, and jobs.

Authentic means working in a hands-on mode with the physical and social world, in addition to and in interaction with abstract symbols and words, and electronic representations such as television provides. The Big Dig offers a wide variety of places and phenomena for students and teachers to conduct empirical investigations in their own neighborhoods—physical construction, utilities infrastructure, wildlife, vehicle traffic, people's opinions, newspaper and television and radio, historical artifacts. Rather than using electronic media in a way that removes people from their physical and social community, the Big Dig scenario uses electronic media and tools to help reconnect people to their hands-on world. This focus on the learner's interaction with the physical world is important both from the perspective of individual cognitive development and the from the standpoint of the health of the planet.

Authentic means learning something at the time a learner is ready and motivated to learn it—perhaps because it is needed to solve a problem or complete a project, or perhaps just from developmental readiness, or curiosity, or social pressure—rather than in a preset curriculum sequence. This is very difficult for learners and teachers to achieve without the support and accessibility of experts and a large repertoire of instructional materials (12). The combination of the Big Dig and the technological and informational infrastructure provides a set of conditions that make just-in-time learning plausible, if not consistently achievable. In the tunnel team vignette some students needed to advance their skills in mathematics to make progress on their tunnel simulation. The teachers were able to draw upon expertise from national sources (e.g., the Geometry Forum), local industry (applied mathematician from a CAT contractor), higher education, and the CWEIS itself (Big Dig task bank) to create appropriate just-in-time learning opportunities for these students.

Authentic means continual learning. A basic premise underlying our vision is that everyone needs to be learning in our rapidly changing world. Recently, many studies have found far too many adults to be woefully lacking in basic literacy (19). At the same time, highly trained professionals, such as engineers, need constant upgrading of their skills and knowledge.

Authentic learning often occurs in an interdisciplinary context, rather than in separate subjects and isolated topics; working on a problem in depth, rather than covering many topics superficially (3). Thematic, interdisciplinary investigations and project-based learning are becoming more common in schools today. They are usually of short duration and there is not enough time to develop the deep underlying concepts or the skills needed to achieve strong discipline. Therefore many attempts at project-based learning are superficial, lacking in deep understanding of underlying concepts or analytical discipline.

The long duration of a Big Dig theme could provide the years needed to build a coherent interdisciplinary curriculum and repertoire of high-quality learning materials. In the Big Dig scenario, students build an increasingly complex and deep understanding from year to year. A student gathering opinion data from local business people may not have all the skills needed to analyze that data meaningfully in a short project. In the Big Dig scenario, that student might revisit the cumulative data on business opinions the next year, and would then have opportunity to learn more advanced statistical analysis concepts and skills in the context of data with which he already is familiar and personally invested. Because the real world of the tunnel project keeps changing (e.g. perhaps opinions of the market merchants change in a year due to changes in the parking situation), the project could remain fresh and alive—unlike having to repeat a chapter in a textbook (89).

Authentic means working directly with people from other places and cultures, rather than only indirectly through books (85). In today's large metropolitan areas, there are different neighborhoods made up of people from a range of places and cultures. Typically there is little interaction among these separate neighborhoods. A metropolitan-wide theme as encompassing as the Big Dig could be used to provide opportunities and motivation for learning from each other. For instance, students in Cambridge might ask students who live beside the entrance to the tunnel to collect samples of traffic data for their study of the changing traffic patterns over time. With the National and Global Information Infrastructure, students can also reach outside their geographic region for collaborations and resources. The history class studying native American artifacts could correspond directly with native American and indigenous scholars and students around the hemisphere.

Authentic learning often requires teamwork. Different members of the team have different skills, interests, and knowledge to contribute to solution of a complex problem (25). In a context such as the Big Dig scenario, teamwork is natural and logical because the learners bring a wide range of backgrounds and capabilities to the task. Teamwork is becoming more typical in modern corporations and business situations (8, 22, 24, 46). In typical schools of the industrial age, where learners are segregated by age and everyone in a class is expected to be achieving the same educational objectives at the same time, it is difficult to conduct meaningful, complex projects requiring a wide repertoire of skills and knowledge.

In 1990, over 74 percent of women whose youngest child was between the ages of 6 and 13 were working or looking for paid work (58). One might speculate that the best social arrangement for lifelong learning of both the child and the parent is a community-based structure that supports all ages of people in highly flexible ways—including opportunities for adults and children to learn together. "Over the coming years, society's ability to adapt to the changing needs of working mothers and their children will be increasingly essential to the health and vitality of families and to the well-being of their children" (58, p.23).

Authentic means producing something of real value to someone. In our vignette, for instance, students produced a CAT jobs databank that has real value to their parents and others in the community. Other students produced an exhibit that was visited and enjoyed by thousands of visitors. Others produced a newspaper that provided information to many others across the metropolis. The ability of students and teachers to produce knowledge that is of real value to a larger audience is perhaps the single most important change in education, and is the change most directly facilitated through electronic communications technologies and the information infrastructure (70, 81, 96).

Authentic means using the real tools for intellectual work that are used in the workplace, rather than oversimplified textbook techniques. A real context such as the Big Dig could make it possible for educational purposes to draw upon real-world tools such as the tunnel simulation software, the jobs data-bank, data analysis tools, that were developed for work in the community. As we evinced in the Tunnel Team vignette, the tools used by professionals are not the same as, and are not always directly transferable, for use by children or novices. But the existence of and commitment to a long-term project such as the Big Dig would make it feasible to invest the time and effort in learning, modifying, and applying these real-world tools to education.

Authentic means basing assessment of student progress on performance of real tasks rather than artificial tests. In 1994, many groups are working on new methods of assessing student learning as demonstrated in exhibitions and portfolios (14, 21, 43, 54, 55, 56, 59, 60, 61). This has proved to be a very challenging endeavor but as illustrated in the Tunnel Team vignette it becomes more feasible under the circumstances of a large, continuing, and community-wide theme. The hypothetical assessment specialist in the Tunnel Team was able to draw upon previous years' experience, the specialized knowledge of diverse panelists, the voices of learners and teachers, and an accessible base of information about the educational goals of individual learners and teams.

New Roles for Teachers

In all these instances of "authentic" learning, teaching roles are richer and more vibrant than teachers now occupy. Teachers are guides and mentors and learners, rather than mere dispensers of knowledge. The Big Dig is a real-world event that keeps growing and changing, thus it provides opportunities for teachers to continue their own learning. Teachers build a web of contacts in the community outside of schools to which they can turn to help them in their own and their students' learning.

These new roles are already evolving. A 1990s example is the work of Nick Haddad, a teacher in Fairweather Street School in Cambridge, MA, who has been collecting data from the Boston Harbor for seven years. His "Boston Harbor Data Sheet" included weekly statistics on species of fish caught, imports and exports, ships and their cargo, water and air data, and learning activities that integrate the study of the Harbor into schooling. He worked with over 100 teachers from around the city, and with MASSPORT authority experts. He works with a group of teachers from around the city, and with Harbor authority experts, developing educational activities that draw upon these data. His own continuing learning about the changing ecology and technology of the Harbor sustains his motivation for this work.

In 1994 we have many pioneering projects and teachers who have created learning environments that enable students both to develop skills in using advanced technological tools and to apply those skills to the production of valued products for their community (6, 38). For instance, Randall Raymond, a teacher at Cass Technical High School, is Project Director for "Urban Environmental Education in Detroit." Working with businesses, government agencies, community colleges, universities and research institutes in the Detroit region, he has developed community partnerships and outreach programs. These partnerships enable his students to develop skill in applying Geographic Information Systems (GIS) technology to problems and projects of importance to the partners. The students conduct demographic studies for small businesses, perform resource mapping and planning for local units of government, design school transportation systems, develop a complete GIS-driven management system for the entire Detroit Public School system, digitize the Detroit Public Library system, provide GIS training for urban teachers and members of the community, and participate in internships that help make a productive transition from school to work. The students' involvement in local environmental issues has created many opportunities to build and apply skills such as data analysis and spatial analysis.

Information resource facilitator, assessment specialist, technology expert, team manager and facilitator, child development expert, subject matter specialist-all these multiple roles teachers are now beginning to assume must be understood as unfolding within a team environment. Not every teacher need be an expert in each role. What is necessary, however, are changed expectations for, and conditions within, the profession of teaching.

First, the isolated world of the self-contained classroom must give way to a more open learning community in which teachers have a chance to work with, observe and learn from each other as well as from professionals in other fields. These teachers (and their students) will most likely remain with each other over a period of years.

Therefore, just as families will need more power in exercising choices over their children's education, so teachers will need to exercise increased choice regarding whom they wish to teach with and under what conditions.

Second, teachers must be adequately prepared for the new roles they will occupy, not only through academic pre-service education but through significant clinical pre-service experiences as well. Those coming into the profession will need more supervised experience with a group of accomplished mentors than that afforded by present mostly hit and miss induction experiences (26). Project centers such as CWEIS and BMER can function as professional development schools for these prospective teachers.

Third, a restructured teaching profession and workforce will need to be created. This workforce will include people who come to teaching via non-traditional routes (some of the experts in the Big Dig, for example), as well as different incentives for those who occupy differentiated roles. We will return to this point later in the paper.

DISCUSSION: GETTING FROM HERE TO THERE

A new social compact is assumed in the Big Dig vignette. In the interim, what happens to school districts organizationally as technology reduces the need for geographic continuity within a District? In our vignette, the school and district organization is in a transition phase. School districts exist in their traditional form, and they also participate in a metropolitan collaborative based on the CWEIS. This metropolitan collaborative would not have evolved without the concurrent developments in the digital telecommunications infrastructure across the area in the late 1990s. The CWEIS of 1994 had laid the organizational foundation across the city to take advantage of the evolving telecommunications infrastructure. Thus by 2004 the organizational and informational mechanisms for such collaboration were well established. Many community leaders, television and radio stations, businesses, libraries, local governments, universities, and schools were already collaborating on the development of highly distributed information services. Gradually over the mid- and late-1990s these diverse institutions would have developed the technical infrastructure and skills in order to contribute to and benefit from the metropolitan-wide knowledge base.

Mercedes' "Using Your Brain" module could have evolved to the point where the nine-week project module was commonplace across the metropolitan area. Every student might participate in at least one such cycle during the year. Since the projects were designed to produce and not merely "reproduce" knowledge, they were considered "value-added." Communities might find that the projects made good economic and civic sense. Workplace skills were being developed early; the application to real-life examples immediate.

Support for the project cycles came from the Boston Metropolitan Education Region, a quasi-public organization modeled after a metropolitan transit authority or the TVA (Tennessee Valley Authority, a regional organization). Evaluation of the projects were an ongoing concern of the BMER. Now, it was not only students and teachers who were being evaluated; it was also the effectiveness of the various players who collaborated with the students and teachers. What was it that they all agreed was important for students to know and be able to do? How were they to measure it? And what was their own responsibility in seeing to it that adequate resources and opportunities were created to achieve the purposes stated?

With help from the state and federal government, the BMER-supported projects also marked the beginnings of a new approach to educational finance. No longer tied to the property tax, every family is given a base educational "learning account" to apply to a portion of its educational services. This community learning utility is supported as part of the partnership agreement between government and the private sector within the Boston Metropolitan Education Region.

Financing these innovations in learning and teaching and collaboration and knowledge-building might have been a constant struggle over the 10 years from 1994 to 2004. The Big Dig theme could provide a great deal of financial leverage, in several ways. The television, radio, and newspapers invested in the development of a vast array of information and educational material simply because the Big Dig topic was of great interest to their customers. Schools and community learning centers could have built upon that naturally developing corpus of multimedia material. In addition, school students and teachers would have been able to add to the materials because of their first-hand experience with the phenomena. They could have gathered information from local citizens and experts for free through interviews and questionnaires. They could have gather empirical data from the physical construction sites and surrounding areas without cost. Perhaps most important is that the students' work would have value to the community. In 1999 there might have been enough community and school interest in the Big Dig theme for education that they were able to get the CAT authorities to agree to invest 5 percent of CAT funds into education and training.

Is our vision a utopian one? After all, there is nothing new in arguing that technology is soon to exert a profound influence on the institution of schooling. The literature is replete with boastful predictions of major changes that somehow never materialized. What is new, we have argued, is a set of circumstances that make this argument more compelling than similar ones of the past. First, the use of technology within the society is rapidly becoming ubiquitous and necessary for economic survival. Second, the kinds of technologies being developed and deployed are, unlike their antecedents, of a kind that exemplify authentic and "constructivist" approaches to teaching and learning. Finally, the new technologies, especially within the communication field, have already demonstrated the potential to transform the boundaries of teaching and learning.

All this, however, remains speculative. Unlike Lew Perelman's *School's Out* (77), our scenario is not depicting a world of isolated and terminal-bound individuals pursuing an isolated, atomistic vision of "life-long learning." We do not challenge the need for the underlying "social capital" currently being provided for by the institution of schooling. In fact, we believe one of the more serious problems facing contemporary education is the *lack of adequate social capital* (110). That is one reason why we support community-oriented, project-based education with its long period of social and intellectual apprenticeship. We question whether traditional schools, with all their existing social and organizational baggage, can any longer accommodate the profound changes technology is already having on our world while enhancing our children's ability to learn, live, and develop comfortably within it.

The task of public policy, then, is not one of exercising unbridled imagination or passion in pursuit of some technological garden of Eden. Instead, it is a more difficult one—that of sustaining critical public engagement with the present while simultaneously creating incentives that might bring to scale those fledgling developments we decide as a society are most in accord with what is possible and desirable.

Three Contexts For Change

Based on our experience in utilizing technology to transform schools (18, 39), we suggest that there are three distinct but related contexts for change that are critical in transforming the rosy vision we present to one that is attainable. The first context is that of integrating new technology tools and the developing information infrastructure of which they are a part. Second, are issues and challenges associated with incorporating novel approaches to teaching and learning made possible by the new tools and infrastructure. The third context for change concerns the creation of a hospitable political, economic and organizational environment necessary to develop and sustain the visions informing the Big Dig.

Institutionalizing Change: Technology Tools and Information

How to integrate tools and information infrastructure? All the separate technological tools being used in the Big Dig vignette are in use in 1994, although their use today is not as seamless as we portray in the scenario. The first major difference, then, between 1994 and the Big Dig scenario is to be found in the seamless environment of technology and information infrastructures, and the fluency with these tools are used to design and enhance learning experiences.

The *technological infrastructure* includes such components as computers, local area networks, telecommunications, and the equipment that connects all of these to metropolitan, national, and global networks. This infrastructure is just now beginning to change the landscape of American education. Client-server technologies, for example, now make possible decentralized control over the local educational environment. In particular, integration of LANs and WANs, combined with a new generation of servers that are user-friendly, now allow teachers and students to more effectively design and manage their own educational environment.

The *information infrastructure* includes the technological infrastructure plus the information and organizational arrangements that make the educational environment of the Big Dig vignette possible. “Information” is used in its broadest sense, to include such things as:

- the Big Digger newsletter published by the students;
- the 10-year archive of interview data from Haymarket vendors; the database management systems that enable users to create the cumulative archive of interview data;
- the pictures and annotations of the Spectacle Island artifacts on the CWEIS Web; video materials gathered by students on the ecology of the harbor;
- the economic data on the CAT project, and related scholarly papers on economic models being used by the students for their senior thesis; data analysis tools used by the students to analyze and interpret such data as the vendor interviews and the economic data;
- the software and locator directories that make it easy for the Tunnel Team to connect via videoconference with Azikwe’s mother’s office and the other schools in metropolitan communities;
- the tunnel simulation software demonstrated by Azikwe and his mother; reference data on the various components of the tunnel simulation, such as specifications on performance of materials;the students’ tunnel simulation and the simulation-building tools used to create it;
- the shared workspace software tools that enable local and remote participants to observe Azikwe’s computer screen during his demonstration;
- the collaborative notebook used for brainstorming and documentation in the Tunnel Team workshop;
- the assessment archives from last year’s Tunnel Team exhibitions; the database of expert reviewers willing to participate in assessing student work; students’ personal development plans; the Tunnel Team’s educational goals;
- the Big Dig educational task bank of lessons and learning activities;
- network agents and intelligent navigational agents that enable the teacher to locate the Geometry Forum; the people and information provided by the Geometry Forum
- the “fair use policies” agreed to by the CWEIS community; and
- the Big Dig jobs bank maintained by high school interns and the city CAT authority.

In our scenario, nearly all of these informational learning components have been constructed through the collaborative efforts of citizens as a byproduct of their learning activities.

In reality, in 1994 there exists very little advanced development efforts that would create and deploy the kinds of resources, tools, and services needed to support the Big Dig vignette. The kind of information infrastructure that is implied and reflected in the vignette is nearly opposite to the kinds of “Information Superhighway” development activity underway in 1994 by the telecommunications and entertainment industries, and other commercial enterprises that control the evolution of the infrastructure. In general, these developments aim towards a view of people as consumers of information rather than producers of knowledge. Funding is practically nonexistent for the development of services, tools, resources, and know-how that would provide the appropriate underpinning for educational experiences such as those reflected in the Big Dig. Every individual project and community has to develop such infrastructures on its own, and none have funding for such purposes, if those services and tools are accessible at all. Localities and states do not fund development of software advances. The federal government has almost no mechanisms at all for funding of software development or deployment in the context of supporting reform of civilian education.

Institutionalizing Change: Teaching and Learning with Technology

Integrating learning tools with an information infrastructure requires a different view of what constitutes a "learning curriculum." The Big Dig participants' information handling, problem-solving, and higher-order thinking skills perhaps provide the most dramatic difference between 1994 and the scenario for 2004. In the vignette, such skills are exemplified in the following ways:

Quality

- the quality control processes built into the student newsletter effort, such that the students' work is usable by professional journalists

Design

- the assessment group's ability to formulate a two-pronged strategy for this year's exhibit assessment, taking advantage of different kinds of input available.

Communications

- the ability of both children and adults to communicate effectively in writing, speaking, and visual media;
- the teaching team's ability to communicate their needs to a distant expert in geometry education; and
- the CAT teenager's ability to explain the organization of the Big Dig Jobs Bank and the institutional context for that effort.

Collaboration

- the ability of people to spontaneously form efficient working teams;
- teacher Elaine Smith's ability to choose the appropriate collaboration tool at the time it was needed for efficient work in the day-long meeting, and the ability of the workshop participants to access and use the tool with fluency.

Analysis

- The high-level analysis skills of teachers and students capable of formulating a comparison between this years' interview data and prior years' study methods and findings;
- A student's ability to envision the usefulness of a side-by-side comparison of two simulation systems representations in the tunnel simulation system;
- A student's ability to conduct a critical analysis of the user interface of the simulation system in relation to the requirements of a large public exhibit; and
- The ability of the Somerville teacher and students to make a quick critique of the draft assessment plan, see it's major flaw, and intervene in a timely manner.

Media

- the students' skill in producing high-quality digital images of the native American artifacts, suitable for publication on the Web and enabling analysis and commentary by distant scholars;
- the high-quality videos produced by students documenting the tunnel and artery traffic; and
- Student fluency with image processing techniques enabling them to conceptualize how to compare current digital images and images from a 10-year-old video.

Information Retrieval

- The ability of the student assessment specialist to locate relevant archives of information concerning individual students, teams, educational objectives, historical assessments, and assessment panelists;
- The teaching team's ability to search the Big Dig educational task bank for materials relevant to the Tunnel Team's needs in mathematics, and to make a quick evaluation of those materials;
- The ability of the volunteer worker at the community learning center to teach Mrs. Maturana how to use the jobs databank, and how to make a live visit to the CAT administration building.

Investigation

- the complexity of the economics project undertaken by the high school seniors.

Learning and Cognition

- A community college teacher's recognition of the utility of the tunnel simulation system for his technician students;
- The engineer's recognition of the similarity between a new professional engineer's learning task and the learning task of a group of schoolchildren;
- A child's ability to envision the use of tunnel traffic data to create an interesting game for adults; and
- A teenager's ability to assess the complexity of the tunnel simulation in relation to the capabilities of her younger teammates.

Science and Engineering

- A teacher's insight about the usefulness of the tunnel simulation for identifying assumptions about structural properties of the tunnel tubes, and her understanding of the value of this activity for the students; and
- A teacher's ability to see how to create a performance test of student understanding of physics by using an operational simulation system.

Yet getting from here to there will not be easy. One of the more difficult areas to address is how to integrate the use of technology in teaching and learning so that it becomes an everyday occurrence in everyone's life.

At present, this integration is the exception, not the rule. More often, as in drill and practice software or traditional ILSes (Integrated Learning Systems), technology is employed to do what textbooks now do. Alternatively, technology is often used exclusively as a "tool" without regard to the quality of the learning it is meant to enhance. In the former instance, the curriculum remains traditional, wed to scope and sequence-oriented subject matter, often with a deadening emphasis on drilling in the "basic skills." In the latter instance, the technology applications can be quite advanced and "constructivist" (email, hypermedia, etc.), but lack sufficient depth of engaging content or context to justify the effort. In both instances, the source of the difficulty is not the technology; it is the curriculum.

Changing the curriculum so that technology can be employed productively is not easy. The national standards movement could prove useful here-providing it results in frameworks that resist dilution and in assessments that resist simplification. Also helpful is widespread interest in the development of project-based curriculum that require teachers and students to orient their demonstrations of learning to significant "out of school" contexts. Emphasis on "school-to-work" transitions might also expedite the kinds of curriculum changes that require a more significant integration of technology.

The unremarkable "ordinariness" of what this technology use might look like in both the content and setting of "real school" is what we attempted to depict throughout The Big Dig. The educational reform efforts of the mid-1990s share a profound shift in emphasis from the content-memorizing paradigm of the past to a paradigm of learning that demands high levels of skill in collaborating, communicating, solving problems, managing information, and the production of knowledge. This has been accompanied by a fundamental rejection of the belief that only a few educated people are required for an industrial economy, to the belief that everyone must be fully educated to participate in a knowledge-based society.

In reality, the Big Dig scenario reflects a high level of cognitive and social functioning with the support of appropriate technologies-a level unlikely o be achieved by 2004. In 1994 there exists almost no research that would lead to the theoretical and empirical knowledge base needed as a foundation for these educational changes. Public monies that currently are being expended in this arena are for deployment and implementation, not research. The Big Dig scenario implies all sorts of understandings that simply do not exist in the current state of the art-understandings of cognition and learning and instruction in the context of very complex, information rich, dynamic situations that have rarely been the context for educational or cognitive research. For instance, currently there is no research on how learners become fluent with image processing or the role of such fluency in novices' development of understanding of dynamic processes (9, 91). There is almost no research underway on appropriate tools for novices' construction of dynamic models and simulations and the cognitive processes involved in such construction. Ironically, at the time local, state and federal education agencies are spending millions to connect schools to the NII and to acquire related computing equipment, there is almost no research on acquisition of information handling skills in the context of very large information space, and their appropriate incorporation into school curricula and practice. Human-computer interface issues such as understandibility and standardization of iconic representations are de facto resolved by software publishers on the basis of idiosyncratic intuitions, with no grounding in empirical research. There is no research underway that would help to inform or establish the kinds of community-wide educational assessment and quality assurance processes and standards reflected in the information infrastructure of the Big Dig scenario.

How inclusive can this ambitious curriculum be? Reviewers asked, will it work for the "bottom half" of teachers and students? This question suggests that there might be a permanent "bottom half." We reject this notion. As Stevenson and Stigler have pointed out in their 1992 comparative study of American and Japanese and Chinese education, the poor achievement level of American students has more to do with our culture of learning than with any presumptive inequities in innate intellectual endowment (92). Setting high standards and expectations for all people, especially in the early grades, instituting a more rigorous and challenging curriculum, and emphasizing "effort" over "ability," will help raise the "bottom half" more than measures whose net effect is to exacerbate, not solve, inequity. In short, there is no reason to believe that there is a permanent bottom half.

Thinkers such as Howard Gardner have pointed out that schools, with their narrow range of individual options and scope and sequence curriculum, often tap into only a limited range of "intelligences" and by so doing, miss the opportunities to engage and develop the talents and proclivities of many students (20).

Authentic Learning: As Opposed to What? Changing the curriculum does not mean that teaching and learning will thereby become effortless. We have been careful not to romanticize learning. When, for example, Azikwe's mother points out to the student Meera that the software program used by professional engineers is different than the students' program, the underlying reason is that the students' program has been created to reflect a controlled learning environment—an environment that is not, nor cannot be, completely "authentic" from the perspective of a professional engineer. Similarly, the utilization of the Swarthmore Geometry Forum by the Tunnel Team teachers is meant to show that there will be times at which specialized instruction (in this case, Geometry) is necessary, though the manner in which it occurs (its "just-in-time" quality, for example) distinguishes its use from traditional scope and sequence pedagogy and curriculum.

Learning is not always fun, engaging, or relentlessly faithful to the real world. It can on occasion require the repetitive performance of tasks or intellectual battle with concepts and theories that are unfamiliar, removed from "reality," even somewhat contrived. That is one reason we believe that paying attention to standards, to what students are expected to know and be able to do, is critical. Unlike past attempts at making education "relevant," contemporary preoccupation with authentic learning is grounded in the belief that there should be explicit habits of mind, competencies and core knowledge that all students are expected to master.

The Tyranny of Time and the "Schedule." What goes on in most schools is often determined by the school schedule (62). Forty-five-minute periods, bus schedules, and rigid work rules imposed by teacher contract, can disrupt the flow of time in which active and engaged learning occurs. Until this changes, it is unlikely that significant numbers of students and teachers will be able to incorporate technologies in a more challenging curriculum. We have already suggested that moving some of the work of schools to outside the school will help free students from the stranglehold of the daily schedule.

But more is needed. In order to make technology an integral and institutionalized part of learning, schools must take seriously the notion that people learn in different ways and at different rates. Arbitrary assignments of students based on age must cease, and more flexible grouping and teaming practices must become commonplace. A central point of our Big Dig scenario is the creative use of computer and communication technologies to help overcome the tyranny of time and the complexities of scheduling group work.

Professional Development: Unless there exists a requisite level of proficiency with (and access to) the various tools and applications, they will not be used at all, much less creatively. Professional development must be continuous; it must have immediate use in instructional contexts; and it must, ultimately, be localized within the learning community. Tools used in professional development must be available for use within the community when and where they are requested.

Phasing in Technology Use: It is not always desirable to begin in a technology-rich environment. Our experience in the Co-NECT restructuring project, in fact, has been the opposite. Unfamiliar technology can have a "smothering" effect on students and teachers. It is often better to phase in its use, so that the instructional, social and physical environments have a developing and organic relationship to one another.

Institutionalizing Change: Politics, Economics and Organization

Communities, Unions and Politics: Who will support the vision? There are a number of different components to this question:

a) **First, what makes us confident that there are enough "experts" out in the community who are willing and able to spend the kind of time with students that the vignette's experts (engineers, public officials, college professors) were willing and able to spend?** In fact, we are *not* confident that this will occur on the scale necessary to realize our vision. To be sure, there will always be a certain number of individuals who happily and selflessly devote their time to education. But we also believe that incentives will have to be created to bring this vision to scale.

Demographics could prove key in making these incentives salient. For example, consider the following demographic projection: While the youth population (10 to 17) is shrinking from 34 percent of the nation in 1970 to 25 percent in 2000, there is a corresponding rise in the over 65 population from 20 million to 40 million during that same period of time (and a rise to 65 million in the year 2030) (31, 32). Healthy and still productive, the over-65 population will most certainly want to extend its stay within the workforce.

From a public policy standpoint, therefore, measures should be considered that might aid in the restructuring of the educational workforce and at the same time, meet projected workforce realities facing corporations, public entities, and institutions of higher education. It is possible, for example, to imagine a new category of "semi-retired" personnel whose benefits remain intact, but whose workloads and salaries are adjusted to allow for civic-oriented contributions, such as becoming educational mentors. A combination of tax incentives and the resultant opportunity to restructure their workforce might prove attractive to both the public and private sectors.

b) **Will teacher unions buy in**? Not likely, given the present political infrastructure of American education. As long as the agenda of local collective bargaining is determined by the existing political and institutional framework of education (school districts, outdated labor law, etc.), there is little likelihood that unions will abandon "hours, wages, and working conditions" as their central purpose or that they will welcome the inclusion of non-dues-paying community experts into their ranks.

At least two changes will have to occur to alter union opposition. First, the political structure upon which union structure is mirrored—e.g., local school districts—will have to be reconceived. And second, there will need to be created positive incentives for unions to change their basic orientation and purpose.

As to the first change, we already see the emergence of alternative political structures within education (such as charter schools and expanded public school choice) as potentially significant developments. These alternatives have begun to exert decentralizing pressure on centralized union rules and regulations as well as school board rules and regulations. Simultaneously, school finance is undergoing taxpayer criticism and extensive review. As states seek funding alternatives to their systems' present reliance on the local property tax, it is conceivable that some of the local focus of economic and political decisionmaking might shift as well. If this occurs, the focus of local unions interest might change. The second change necessary (new incentives) might occur in measures such as providing greater teacher decisionmaking and influence in the area of professional development in return for a relaxation in union determination of "hours, wages, and working conditions," new pay schemes (pay for performance, differentiated pay ushered in through the National Board for Professional Teaching Standards, etc.).

What will happen to school districts as the vision unfolds?

a) **A system of schools rather than a school system**: The organizational context enabling instructional changes like those above, requires less control and more facilitation from the school district central office.

This move toward greater decentralization (school-based management, charter schools, etc.) might, as mentioned, eventually result in a radically different institutional context for education. In the short run, however, increased use of technology in education will raise, as it has done in other areas of government and business, serious questions regarding privatization, the role of middle management and the possibility of decentralized accountability. In general, we believe that schools organized around shared educational visions will be more productive than those that are grouped together on exclusively geographical criteria (30).

b) **Restructure administration**: At least in the near term, school districts will remain the primary administrative organizational agents responsible for schools. If so, much needs to be done immediately to avoid inefficiency at the central office level. Technology planning and implementation is often plagued by archaic central office structures. In particular, facilities, instruction and administrative functions are often maintained by separate line and staff structures.

When this occurs, inefficiency results. Hardware is ordered centrally without regard to the requirements of the applications it will be running; facilities renovation is planned without accounting for the telecommunications or video needs of the local educational program; technology acquisition/maintenance is placed in budget categories and lines that make them susceptible to year-to-year fluctuations in funding, rather than being placed in fixed line items such as utilities.

c) **Integrate administrative and instructional technology**: The history of technology in education has been a bifurcated one: Administrative technology has developed in isolation from its instructional use. Most often, the central office has been the “data processing shop.” Instructional use of technology (electronic portfolios, access to databases, etc.) has arisen independently.

Today, it is important to combine these two functions so that: decentralized learning communities have access to information when and where they need it; (health records, budget, car registration, milk count, etc., as well as educational), reporting requirements are made helpful, not burdensome, to these communities; and we avoid the inefficiencies of separate and redundant technology infrastructures.

d) **A school is not a building**: Or at least not the egg crate carton structures that have become identified with school facilities. The new technologies require facilities and infrastructures that can accommodate them. After all, it does little good to have schools equipped for the 21st century but designed for the 19th (insufficient wiring, inadequate, dysfunctional space, etc.). Over half the existing school buildings in the country were built in the 1960s, with an expected shelf-life of 35 years. They were built in a fairly standardized manner and without regard for the eventual inclusion of technology. School districts, especially ones that no longer design schools according to the principle that “one size fits all, “ will need help in effecting a transformation (25). The Department of Education and/or private foundations should consider reestablishing a “Educational Facilities Laboratory” (similar to the one created by the Ford Foundation during the building frenzy of the ‘60s) in order to disseminate current information and promising models of new technology-rich schools. The new “School Facilities Infrastructure Improvement Program” approved by Congress for FY 1995 is a small step in the right direction.

e) **Student mobility**: Another impediment to creating structures that are amenable to sustained flexibility in the learning environment is student mobility, a situation particularly acute in many urban areas. It can be counterproductive for a student to work in a flexible structure that incorporates the creative use of technology, if when that same student moves during the course of the year, her new school incorporates a traditional pedagogical structure and schedule. It is important, therefore, to seek ways in which continuity of educational experience over time persists across traditional attendance boundaries. Increased parental choice, appropriate transportation arrangements and use of networks for continuity of experience from one educational setting to another are examples of the kind of thinking necessary to solve this problem.

f) **Many places for learning**: In our scenario, people are physically located in many different places throughout the city as they participate in learning activities. The technology enables great flexibility of place.

How will this vision be financed? We have already indicated a number of ways in which the financing of elementary and secondary education will have to be reconceived if the vision of The Big Dig is to become generalized. In what follows, we elaborate on these.

How will the teaching workforce be structured and supported? The lion’s share of every educational institution’s budget is consumed by personnel costs. There are at present some 2.5 million K-12 teachers. By and large, these teachers have been “trained” and compensated as if they were interchangeable parts. The kinds of technology-intensive, project-based education we have sketched will require a fundamental restructuring of the teaching profession. We have already discussed the various new roles that individual “teachers” are now occupying and will increasingly do so. The structure and composition of the workforce as a whole will also experience radical change. More specifically:

- There may be fewer “professional teachers” required. Instead of 2.5 million K-12 teachers, it is possible to imagine a situation in which the profession is restructured to accommodate a permanent “teaching force” far fewer in number. This number would command significantly higher average salaries than at present, meet more rigorous entrance requirements (certification as opposed to simple licensure), and held accountable for student results.

- They might be supplemented with a large number of people who would be paid substantially less. These people (engineers, scientists, writers, artists, etc.) are the experts with whom the teachers and students work directly. As a group, we could expect that these individuals would have their basic health and retirement benefits covered by their existing employers.
- College graduates who attend college on forgiveable loans might constitute a third element of a restructured workforce. Upon graduation, these individuals would be employed as interns in various educational settings. After a number of year's service, the debt incurred from their college loans would be forgiven.
- This restructured three-tiered work force would require significant use of technology. The widespread availability and use of different kinds of technology allows for a more efficient deployment of personnel, greater use of economies of scale, and increased personalization.

How will new organizational structures be created and financed? The Big Dig envisioned the creation of a fictional entity, the Boston Metropolitan Educational Region, as a cooperative venture of local, state and federal government with private industry. If, as suggested, school districts give rise to organizational structures more attuned to out of school learning and common academic purpose, entities like BMER might become typical. These entities could be financed through a combination of various means:

- The expenditure of monies drawn from "lifelong learning" accounts—that is, accounts created and made available to citizens at birth and expended throughout an individual's life by enrolling in any number of various learning/project centers.
- The ability of entities as nonprofit educational corporations to earn revenue by creating socially useful products and/or services, and the leasing of space.
- Industry (biotechnology, finance, software, etc.) support for these entities as training and school-to-work transition centers.

How will space for project-based education be found and financed? A number of possibilities exist:

- **Satellite learning centers**: In Dade County, Florida, a few large businesses built public educational facilities on their premises. By doing so, they have provided many of their employees with an additional benefit and incentive—that of being more directly connected to their children's education.
- **Shared use facilities**: One possibility is shared use of space by constituencies other than K-12. These facilities could be shared, for example, by ongoing community services (such as libraries and other municipal buildings) or corporate job re-training centers.
- **Revitalization of the inner city**: Through measures such as enterprise zone legislation, it would be possible for boards of education to enter into partnership with redevelopment authorities. They might lease and renovate neglected buildings to be used as educational project spaces or cooperative centers by public-private partnerships.
- A federal agency or department (HUD, Department of Education, etc.) or a national foundation might establish a National Educational Facilities Laboratory, whose purpose would be to disseminate best practice and advice on the renovation and construction of new school designs.

How will we organize and finance the research and development needed to make informed use of the considerable technological potential available to us for educational purposes ? What little educational research has been supported over the past 100 years was conducted in a context of incremental improvement of learning, very modest restructuring of learning environments, and minimal use of advanced technologies. Such an enterprise is practically irrelevant to the rapidly changing social and technological conditions at hand. Because education and schooling are seen to be so lagging in the technological change processes underway in other sectors of society, policymakers, decisionmakers and grass-root innovators are totally focused on issues of deployment and implementation at the exclusion of development of a base of knowledge that would enable more rational and cost-effective implementation. Federal agencies are supporting "demonstrations," "systemic initiatives," and "scaling up" activities, rather than accompanying these with a focused quest for understanding and knowledge building.

Given these current political conditions, the only plausible strategy we can think of for supporting the creation of new knowledge and an understanding of learning and cognition in the context of educational technologies and reform is to attempt to do so as a part of implementation projects. Government agency programs that are supporting innovative projects involving learning and teaching and technology could require that some meaningful percentage of the effort be devoted to systematic investigation of learning and teaching processes in the context of their innovations, and to the widespread dissemination of such knowledge. This strategy makes the quest for understanding an integral byproduct of operations and could result in a more secure foundation than is presently being built.

SUMMARY

Technology serves a dual role within education. First, it can be used to support lifelong teaching and learning that is "authentic," and, second, it can catalyze the institutional changes necessary to usher in authentic teaching and learning. The Big Dig reflects both tendencies.

The seeds of technological change have already been planted, and as a result, the system of education as we know it will become radically transformed in the coming years. In particular, we believe that:

The institutional framework of education will shift from an emphasis on "schools" to an emphasis on "communities." The primary functions of schools to date have been custodial and administrative. Economic and civic changes demand that the institutional framework of learning be widened so that these key functions be accommodated. Communities are the natural place to locate this institutional framework.

This trend is already underway. For example, many have argued that it makes more sense to "educationalize" the agenda of social service agencies than to integrate yet another function on top of the academic mission of schools. It is a short step from this argument to one that calls for an integrated community-wide structure that can accomplish all the myriad missions connected with youth (health, employment, etc.). The technology, moreover, is now in existence to effect the communication necessary to make these new structures operationally effective.

The financing of education will shift to an emphasis on "lifelong learning." Everyone is agreed that school finance must change; the question is how? While this will not be easy, the time has come to create lifelong learning accounts. Educational opportunities will be defined to include access to the technologies upon which they will increasingly depend. The origin of these accounts might be initially located within community, regional or state entities.

"Teaching" will be ubiquitous. The role of teachers is already undergoing profound changes, and this trend will continue. Teachers will be integral to virtually every aspect of social and economic life. With the intellectual distance between learning and work disappearing, teaching will no longer be considered an occupation relegated to any one institution. Providing for a continuity in educational experience that is no longer institutionally based, teachers will need to demonstrate technological proficiency in order to accomplish their tasks within a wide variety of settings.

APPENDIX B REFERENCES

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Appendix C The Future of Teaching

C

"Education is not preparation for life, it is life itself.—John Dewey

November 7, 2005. You are a member of a Program Quality Review panel for the California State Department of Education. The panel is beginning the first formal review of one of the most successful school districts approved under the Charter School District Initiative of 2000.

Over the past five years Pacifica school district has become a model of how changing teacher-student and school-community relationships can create positive learning environments. Unlike other models that begin by changing instructional practices, in this design it was the job of teaching that was the primary focus of change. This Charter District radically altered the roles and responsibilities of all positions from teacher to superintendent.[1]

PLANNING OFFICE OF CENTRAL ELEMENTARY

Your day-long assessment begins in the planning office at Central Elementary School. The panel is now meeting with the Senior School Planning Team composed of four master teachers at Central Elementary: Barb Milner, Nancy Broyles, Ben Barrel, and

[1] This paper is written primarily in the "voice" of teachers to reflect their central role in educational change. My experience with educational technology has reinforced my belief that it strongest potential is as a communication tool to amplify the voice of teachers and students. Without their voices, there can be no significant educational change. As much as possible, I want to share the visions that have evolved from my work with some of the best educators in the world. This paper is more about the process that took place among the players in this scenario than it is the end result. For a much detailed description of how current reform efforts are supported by exemplary use of technology, see M. Riel, "Educational Change in a Technology-Rich Environment," *Journal of Research on Computer in Education*, vol 26, No. 4, pp.452-474

by

Margaret Riel

Interlearn

Josie Rowe. Barb and Nancy are co-principals at Central. Ben is working on a curriculum committee at the State Department of Education. Josie is part of the district's Superintendent Team. You are listening to Co-Principal Bab Milner describe the history and rationale for setting up a Charter District model.

Barb Milner: By the end of the 20th century, it was clear that schools designed on the "industrial model" to transmit knowledge were no longer serving students, teachers, or our communities. But it was hard to find models for change. There had been more than one "education president," and "education governors" had led many states. Some of these leaders believed that technology was the answer; they set up models to "infuse the school" with advanced technology, hoping student skills would rise dramatically. But research showed that while students were able to learn how to use the technology, there was no significant improvement in academic achievement.[2] Real educational change required changing the relationship among teachers, learners, information, and experience.[3]

As you know, the first attempts at changing these relationships were mostly isolated. For example, the "Charter Schools Initiatives" in Minnesota, California, and other states led to some limited success in educational innovation.[4] In these schools, teachers, parents, and members of the community could develop plans for an individual school without having to follow all of the established state or district regulations. But these efforts divorced the school from valuable district, state, and national services. The "Star Schools Initiative" in the early 1990s helped science teachers come up with "action plans" for science education, but these innovations were not well integrated with other aspects of school learning. Privatizing public education was marginally successfully when the "public" children came from relatively privileged backgrounds. But these schools did not provide the promised "quick fix" to address complex social problems faced by schools across the country. They often concentrated on low-level skills with a focus on test taking. These isolated attempts were neither cost-effective nor efficient in providing quality education to all children.[5]

In the mid to late-1990s, the rapid growth of the National Information Infrastructure pushed teachers to the limit with new responsibilities. Before long teachers everywhere were overwhelmed with electronic mail and conferences on every topic.

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[2] One the most dramatic efforts of infusing schools with technology is the "Apple Classrooms of Tomorrow" project. The extensive research on student achievement in these classrooms show that the students did about as well as they might have without all of the technology. That is, that they were able to learn how to use a complex set of tools without and loss of school achievement. But this research failed to validate an assumption that and infusion of technology would be the simple answer to the problems faced by schools. Dwyer, D. (1994) "Apple Classrooms of Tomorrow: What We've Learned," *Educational Leadership*, vol 51, No. 7, pp. 4-10.

[3] Many of the school reform initiatives suggest that the failure of schools is directly related to existing power relationships in schools. Specifically these views can be found in S. B. Sarason. *The Predictable Failure of Educational Reform*. (San Francisco: Josesy-Bass Publishers, 1990) and in S. Sarason, *Culture of the School and Problem of Change*, (Boston, MA: Allyn and Bacon, 1982).

[4] For more details on the charter school initiatives and their process across the U.S., see, Bierlein, L. and L. Mulholland (February, 1994). *Charter School update: Expansion of a Viable Reform Initiative*. Tempe, Ariz.: Morrison Institute for Public Policy. For a discussion of the California Charter Schools, see Diamond, L. (1994) "A progress report on California's Charter Schools. *Educational Leadership*, vol. 52, No. 1, pp. 41-45.

[5] The current experiment, Education Alternative Inc. (EAI), headed by John Golle, has not succeeded in raising test scores of students in eight Baltimore schools even with dedicating 30 minutes a day to taking drills in math and reading that are similar to those used in tests. Recently the U.S. Department of Education concluded that EAI is not providing special education students needed services in their mainstreaming efforts. There are similar concerns that money allocated for disadvantaged student is not being used for this purpose. The Edison project has set higher educational goals with a longer school day and a longer year but they have yet to demonstrate that they can reach their goals in a cost-effective way. For more information on the issue of privatization of schools, watch for a new book by Thomas Toch, senior editor at U.S. News and World Report, or read T. Toch "Privatization: News form the Front" *American's Agenda*, vol 4, No. 3, pp. 12-17, 46.

We were wasting too much of our most valuable educational resource—teacher time. And students were wasting classroom time on undefined explorations, looking just to see what was there.

As we approached the 21st century we knew that a revolutionary plan for changing teaching and learning was necessary. That "revolutionary" change came when we understood that we needed to create schools where *change was an ongoing process* rather than an end state. Once we accepted this idea, it was clear that we would have to change the way a teacher spends his or her day. And once we got started, we realized that this would only be possible if we changed our educational system.

Overview of Changes in Leadership Roles

Barb Milner: Before we visit the Learning Centers, we want to give you a brief overview of the changes. It has been only five years since we initiated our new plan, although we began planning in the mid-1990s. Before the shift, we kept trying to come up with the right mix of interpersonal and intellectual skills to define our conception of the "ideal" teacher. Some of us experimenting with models of "school site management" wanted teachers to be curriculum developers with leadership roles in organizing the school. But some teachers saw these new roles stretching teachers too far and moving them away from the classroom at the cost of student learning. They wanted to focus on students' learning styles. And then there were teachers who had "had enough." They were tired of having every social problem dumped at the classroom door, being asked to work at the pace of a hospital emergency room without support and then being "held accountable" for all failures. They didn't want another meeting on any topic!

We were getting nowhere. There were so many different skills that defined teaching that reaching consensus about an ideal teacher was surprisingly difficult. And most of our designs were so overwhelming that without changing salaries or adjusting the demands placed on teachers, we knew these "super" teachers were unrealistic. So, we took a different approach and decided to develop a role for teachers with differing strengths and abilities. We wanted to develop a system that recognized achievement but also provided opportunities for people with different talents to play a role in education. One of the most difficult circumstances constraining us was a very lean school budget. Our current plan has evolved from thinking about our options and working together. While it hasn't always been easy, it has been a great experience.

At this point, Barb pauses and looks toward the other master teachers. The exchange of glances seem to underscore the last statement. Ben Barrel continues.

Ben Barrel: We realized that our visions and tools would have to work within the organizational climate of schools. And that climate needed to be one of collaboration. Teachers and students, their relationships to one another and to sources of information and patterns of thought, could not remain insulated in classrooms. The changes you will see today came from increased communication and partnerships among teachers and through relationships we developed with students, librarians, museum curators, publishers, developers, scientists, and researchers both near and distant and at all levels of school leadership. These connections between the classroom and the world have been the path of educational change for us.[6]

We started with changing the teacher's role because we knew that we could not ask a teacher to do any more without changing the dimensions of the job. We were just stretched too thin. We needed to design a system where a teacher's expertise in working with students was rewarded and re-

[6] Case studies of changes that have taken place when school administrators move toward transformational leadership patterns can be found in Leithwood, K.A, & R. Steinbach. "Indicators of Transformational Leadership in the Everyday Problem Solving of School Administrators." *Journal of Personnel Evaluation in Education* vol 4, No. 3, pp.221-244.

spected. But we also wanted a system where the rewards for good teaching *did not result in leaving the classroom.* While I enjoy my work developing curriculum on our state committee, I do not want to give up teaching.

We began to evolve a new plan for teaching and learning as a community. We were well underway when the Charter School District Initiative was announced. It provided the perfect vehicle to test our ideas. We were the second district to have our charter accepted. I had been doing grade-level "team teaching" for a number of years and the idea for Learning Centers evolved from our work. At first I teamed with two other teachers. The hard part was finding time for planning. At the same time we were involving students in more independent project-based learning using telecommunication and multimedia tools. Initially, our School Site Council provided some funds for a long-term substitute teacher who provided some flexibility, but what we needed was what we now call "Learning Guides." Josie, are you planning to describe learning guides now or later?

Josie Rowe: We only have time for a brief description now. Later, when we meet in the business office, I will give you some charts that will help us discuss the economic issues of staffing. Learning guides are para-professionals who help students learn, but they do not have all the added responsibility of teachers. They are not expected to develop curriculum or plan the overall design of the Learning Centers. Learning guides supervise and facilitate independent and group work by students. Since they move through the Centers with the students, they get to know the students well and create a consistent set of expectations for appropriate Center behavior.

As you will see when you visit the Centers, we encourage students to take responsibility and control of their projects and activities. This makes it possible for teachers to work with smaller groups while larger groups of students are working under the supervision of learning guides. Some demonstration or performance lessons by our mentor or master teachers are designed for the whole Learning Center, or close to 100 students. Students move from small intense groups to larger groups both for lessons and for project work.

While learning guides were the only completely new position we created in our district plan, all positions have been significantly altered. Maybe some personal history will help you see this. I was an assistant superintendent in this district at the time we began the process of change. I had been a teacher and I loved teaching and experimenting with different approaches. Ironically, it was my experience working as a teacher/researcher on a university project research team that pulled me away from the classroom. I found it so intellectually stimulating to be a team member with my university colleagues that when the project ended, I was no longer happy only teaching students. While I loved teaching, it was not enough of an intellectual challenge. I found I missed the learning and especially the collaboration with colleagues that had been a part of the research project. There just wasn't enough time in a day of classroom teaching to think!

I took a break from teaching and went back to the university to get an administrative credential and some computer skills. I was rehired by the district as a computer coordinator and then principal of Seaside Elementary. From there I was promoted to assistant superintendent of school services. But from the time I left the classroom, I missed my time with the kids. I had often considered leaving my district position and returning to the classroom—even considering the cut in pay!

The teachers who proposed that all administrators teach expected resistance. They were surprised to find out how many of us missed teaching. Our administrative duties are now spread over four master teacher-superintendents instead of the one superintendent and two assistant superintendents of the past. Each master teacher-superintendent is assigned to two schools. We also work very closely with the co-principals at each school. A master teacher-superintendent rotates to a different pair of schools each year and takes on slightly different duties. In our superintendent meetings, we collectively bring with us a rich and extensive knowledge of our district schools because all of us are teaching. And we work closely with all of the teachers who have been central in evolving this new model. In some ways, our work is that of creating and managing a culture of professional reflection among peers.[7]

Quality Review Panelist: Don't you find it hard to move back and forth between district offices and school sites for teaching? I would think you would waste a lot of time traveling.

Josie Rowe: Well, the easy answer is no, because the district offices are located at every one of our schools. With computer telecommunications, we realized that common physical location was no longer an issue with most of our "meetings" taking place every day online. We sold the district buildings and used the income to build an office complex at each of our eight schools. You will have a tour of these buildings after your visit to the Centers. By locating offices at the schools, we could share equipment and resources which saved money and provided better services to teachers.

Quality Review Panelist: What about group meetings?

Josie Rowe: We often meet in groups of different sizes and the meetings are held at different schools. Sometimes I travel to these meetings, but I also have the option of teleconferencing which works almost as well. We have so many more options for collaborative work than we did in the past.

Nancy Broyles: Access to district offices here at the school is a real benefit for us as you will see when you visit them. But let's move to the topic of Learning Centers. We want you to be in the Centers as the school day begins, so I want to give you a brief overview of our instructional programs.

Overview of Learning Centers

Nancy Broyles: Many of the ideas for our plan have come from our work online with schools around the world. Working with distant teachers has resulted in many new ideas that I don't think we would have had without electronic connections. One of our major concerns was that in the past students were asked to master discrete low-level skills and learn isolated facts. We wanted students to master subject matter in depth, learn how to develop and apply problem solving skills, and most of all learn strategies and develop interests that would help them throughout their lives. It was this thinking that led us to create Learning Centers instead of classrooms.

The Center curriculum is based on the new California Frameworks for Theme-Based Instruction.[8] Ben and some of our district mentor teachers were on the state committees that developed these new curriculum plans. We are very proud of our participation. By making it possible for our teachers to work with the larger educational community, they have developed expertise in national and international arenas which enriches their teaching and brings many rewards to the whole district.

We are now in the second year of our experiment with a new way of grouping kids. We have multi-age learning teams with an average of 85 students to a team. We moved away from age grouping because the competition too often resulted in kids who gave up trying to learn. We found that student interest makes it possible for kids of different ages to work together as partners.

[7] For more discussion on the role of administrators to create and manage collaborative cultures, see Fullan, M. G., "Visions that Blind," and Hagstrom, D., "Alaska's Discovery School" and Schmuck, P., "Educating the New Generation of Superintendents" *Educational Leadership* vol. 49, No. 5, 1992,19-20; 23-26; 66-71.

[8] These documents do not exist but they would be the natural extension of the excellent curriculum frameworks developed in California. Many of the current frameworks celebrate a theme-based structure for learning. But beyond the content, I want to highlight the collaborative process involved in writing these guides. Educators, writers and resource experts work together to create a plan for instructional innovation.

Our emphasis is on participation and accomplishments and not competition and comparisons. We find this cross-age grouping very effective for both younger and older students. Our student teams move to a new Center after a 12-week term with the exception of the five-year-olds team who stay in the same Center all year. Here is a copy of our school schedule showing how our student teams move through the Centers (table C-1). The students are just returning from our first term break. The other handout is a list of the curriculum themes for this year (box C-1). Our primary program and our intermediate program are described in this chart.

All student work is directed toward the Center exhibition[9] which is listed at the end of the term. The whole community looks forward to these days, they are heralded in the local papers and, like parades or fairs, there is a strong feeling of community investment and pride. Local businesses provide resources and business partners join their students to see the end result of their educational help. These "events" are public portfolios of student work—and of the help provided by our community. The students are motivated to do well because their friends and neighbors and online partners will see their work. Parents see what takes place in their school and they are encouraged to evaluate what they see. I wish you could be here for an exhibition. They are a very impressive demonstration of community support as well as an implicit forum of parent education.

Quality Review Panelist: Do all district schools have the same themes at the same time?

Nancy Broyles: No, we rotate the themes. Some repeat on a three-year cycle, others have similar form but take different content each time. This helps with our use of school and community resources. We usually share themes with two other schools each year. This means that community partners like our Pacific Aquarium or the Anthropology Center can contribute on a regular basis to two different schools each year supporting all of our schools equally. Books, CD's and other learning materials move across schools. This means there is a less need for duplication of materials. We have almost all of our educational materials in constant use at one of the schools so we need less room for storing materials. Teachers work together across schools to coordinate and share resources and experiences.

All teachers help in planning the overall design of the learning environments in the Centers. But there are different roles. Each Center has a curriculum coordinator for the humanities and language arts strand and one for the science, technology and math strand. They are "content" experts who coordinate the local and distant resources for designing Center activities. "Team" teachers and learning guides stay with the same group of students all year, moving with them to each Center. They work closely with students and bring a strong knowledge of "student skills and interests" to the collaborative planning. Other teachers are "resource" teachers, who can provide special work in a particular area or for a particular group, for example, bilingual or technology resources. Planning the Learning Center environment means coordination of expertise in academic disciplines, knowledge of the student team, and integration of resources. But now it's time to see how this works in practice. School is about to start.

VISIT TO THE OCEANS LEARNING CENTER

Your group walks from the school planning office down an outdoor walkway past the school-yard full of the noise of kids finding each other and their early morning activities. Nancy offers to take those who are visiting the primary program. Barb leads the rest of the group. You are reviewing the intermediate program and will visit the Oceans

[9] These school exhibitions help make the school the center of the community and learning a valued activity. Students contribute to the community by creating these evolving museums. The term "exhibition" comes from Ted Sizer's book: Sizer, T., (1992), Horace's School, Boston, Mass: Houghton Mifflin, which has influenced many of my ideas on school reform.

TABLE C-1: Central School Schedule, 2005-2006

Sept. 5-9	**Team Orientation Week**
	Student skill assessment
Sept. 12-Dec. 16	**Term 1 (12 weeks)**
Sept. 12	Term 1 begins
Oct. 10	Columbus Day
Oct. 24-28	Half Term Break (one week)
Nov. 24-25	Thanksgiving Break
Dec. 9	Term 1 ends
Dec. 11-Jan. 2	Term Break (2 weeks), plus one-week holiday
Dec. 10, 12	Exhibition Days
	Total Center Instruction Days = 57 *days*
Jan. 3-Mar. 30	**Term 2 (12 weeks)**
Jan 3	Term 2 begins
Jan 16	Martin Luther King Day
Feb 13-17	Half Term Break (one week)
Mar. 30	Term 2 ends
Apr. 4-14	Term Break (2 weeks)
April 1, 3	Exhibition Days
	Total Center Instruction Days = 58 days
Apr. 17-July 14	**Term 3 (12 weeks)**
Apr. 17	Term 3 begins
May 29-June 2	Term Break (one week)
July 4-5	Independence Break
July 14	Term 3 ends
July 15, 17	Exhibition Days
	Total Center Instruction Days = 58
July 16-20	School Reflection and End of Year Activities

School year:

173 days of Center Instruction
5 days of Orientation and Assessment
6 days of Student Exhibitions
3 *days of Reelection & End of Year*
186 days of school for students

Learning Centers\Terms	**Term 1** **Sept.-Dee.**	**Term** 2 **Jan.-Mar.**	**Term** 3 **Apr.-July**
Entry Program			
Tadpole Center		—Team K all year—	
Primary Program			
The Lands Learning Center	Team P-1	Team P-2	Team P-3
The People Learning Center	Team P-2	Team P-3	Team P-1
Our Imagination Learning Center	Team P-3	Team P-1	Team P-2
Intermediate Program			
The Oceans Learning Center	Team I-l	Team I-2	Team I-3
Time Machine Learning Center	Team I-2	Team I-3	Team I-1
Inner & Outer Space Learning Center	Team I-3	Team I-l	Team I-2

BOX C–1: Curriculum Themes

Primary Program Center Themes

The Lands Learning Center In this theme, students explore the different continents, regions, and states, climate and weather patterns, creatures big and small, plants and food cycles, energy, adaptations, transportation, and communication. Many of the Center activities are drawn from the theme curriculum of the National Council for Geographic Education.

The People Learning Center: This theme looks at the organization of people into families and societies They look at how different geographic regions result in different adaptations with respect to food, clothing, family structures, health, and issues of local and regional security. Students will be connected to people in very different living conditions throughout the world, including students who live in homes dug under the ground in the desert heat of Copper Pedy, Australia.

Our Imagination Learning Center: This theme celebrates our ability to think and write about things that “might be” or “might have been''—the idea is to explore ideas that stretch reality. The work in this Center includes a comparison of games and toys used by students' parents with those that are popular with students today. Students will read, write, direct, create and produce. An accomplished poet and artist wiIl help students create images to extend the present into the future.

The Intermediate Program Center Themes

The Oceans Learning Center: This theme focuses on all forms of animal and plant life in our oceans, from the kelp beds to the whales, from the depths of the ocean to the shallow waters of the wetlands and marshes Students will become partners in local environmental projects concerning the preservation of the Batiquitos and San Elijo Lagoons.

The Time Machine Learning Center: Time Machine is a journey through time. The students and teachers wiIl identify a number of places and times to visit and transform the classroom appropriately. Students will research these periods and then act in the role of characters and customs of the past, For the Egyptian period, papyrus is currently growing in our school garden so that students can make papyrus rolls for keeping records.

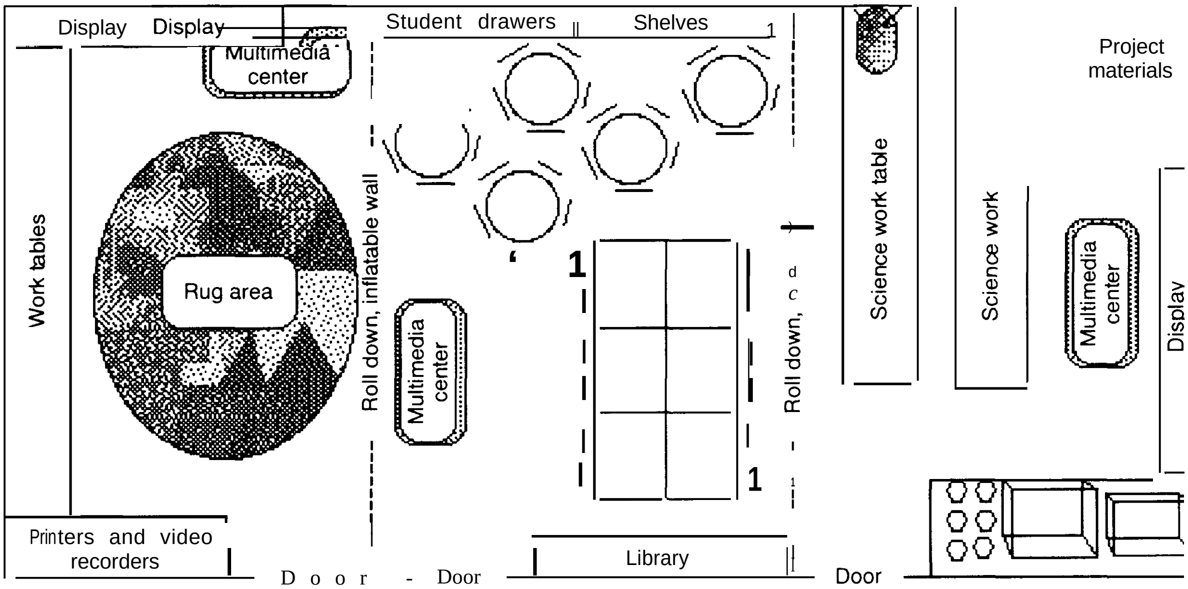
Inner & Outer Space Learning Center: This theme takes students from microscopic cells mostly inside the human body to the very large expanse of the universe. The work in this Center will include discussions of major systems within the human body including reproduction. Students will also examine systems of planets and stars m space. The students will be working with partner scientists from the Space and Science Museum.

Learning Center. You wonder how it is possible for kids of such different ages to work together in one setting.

Barb Milner: This brightly colored area is the Tadpole Center. It is for the five-year-old students. In this first year, teachers focus on getting to know the students and assessing their skills and their interests. In this first year the students remain in the same Center all year. It is a transition year when students are able to seethe structure of elementary school from the comfort of an environment similar to their early childhood experiences.

Two of your team members leave to review this program. As you walk to the other Centers, Barb describes the buildings.

Barb Milner: You will notice that the buildings are not new. We wish we could have started over with a brand new school, but we did not have that luxury. Our school was built during the middle of the last century. The classrooms were well constructed and earthquake-safe so we had to work with the constraints of the old building. As you can see, they are rectangular rooms built along corridors.



When we were planning for our Charter District, we wanted flexible learning spaces—places for small group discussions, for project work, and for large group presentations and demonstrations. The auditorium was not very close to classrooms and it served as the lunch room on rainy days, so it was not a great place for computer equipment. We were stuck on the idea of groups of students in an auditorium with a large presentation system. But as display systems became less expensive, we realized that a number of smaller monitors around a common space was a better solution. This shifted our thinking. Instead of trying to construct a large place to move to when needed, we just took out the connecting walls between three classrooms and created a Learning Center of flexible dimensions. We replaced the permanent walls with those wonderful new inflatable walls that roll down from the ceiling. Have you seen them? Lots of hotels have them for conference rooms. They are strong enough to lean on but they can disappear almost completely. And the new sound-proof covering is perfect for when we need more quiet spaces.

This area is for the intermediate Centers including the Oceans Learning Center. The intermediate teams are made up of roughly equal numbers of 9-, 10-, and 1 l-year-old students. This team is returning from an inter-term break of one week. They will have six more weeks to complete their Center work.

As you approach the classroom, you can see that only the door to the Center room is open and that a few students have paused in the doorway watching you. As you approach, a gregarious boy offers a greeting.

Michael: Hello Dr. Milner! Are these the visitors you told us about?

Barb Milner: Yes, are you going into your Learning Center? Maybe we can follow you.

Michael: Sure, I'm Michael and this is my friend Rio. We'll be happy to show you around.

You *follow Michael and Rio into a very large room (see diagram above). At the right end of the room there are two large tables with trays containing science tools and microscopes with video display monitors connected to them. There are sinks built into each of the tables and some pans of water connected by tubes. Near the front windows are rows of plants with labels, There are a three or four kids watching the fish in a large aquarium. Another smaller aquarium has marsh plants. In the corner of the room are several large cardboard boxes, partially completed signs, and other project materials.*

Directly in front of you is one of the three portable multimedia computer carts and an assortment of tables. The rectangular ones have been grouped together to provide seating for 16 students. There are four students intently working with laptop computers. Off to the side are round tables where a small group of students are working with paper and props. From the ceiling are stuffed paper scale models of whales, dolphins, sharks, and other much smaller sea animals. Along the side are shelves with an assortment of writing and art supplies, including a large row of graph paper and about a dozen calculators, some partially completed dolphins, and meter sticks. There are students taking things out of brightly colored drawers labeled with student names. In the front left corner of the center are two printers and a video tape deck. There is a small group of kids scanning pages that are coming out of a printer. To the right of the door you just entered is a library area with books and magazines, CDs and other resources.

At the left end of the Center is an open area with a brightly colored circular rug. There are kids, some with computers, sitting on the rug with backpacks thrown to the side. At one end of the rug there is another multimedia computer cart. Along the wall is a long cabinet with a work-top.

Everywhere there are pictures and murals of fish, penguins, kelp forests and ocean robotics. At various places there are monitors mounted from the ceiling or on the walls. Throughout the Center about 35 kids work in small groups or alone. The printer is humming and the overall feeling is one of respect for the work of kids.

Quality Review Panelist: Why are you coming into the classroom before the bell rings?

Michael: I like to see if I got any personal mail. Most of us have computers at home, but, like with me, my older brothers never let me have anytime. If we finish our project work in class, sometimes there is time to check mail. But sometimes I get too much mail. Lots of us get to school early and we can come in when we want.

Rio: I'm here now because my group-see them over there—we're working on our performance for the exhibition. We are writing a play and we had some new ideas to change it, so we decided to meet before school to get more time. I better check in—I think I'm late.

Rio goes past the multimedia computer cart and turns to see his image appear on the screen. He types a few keystrokes, glances at the screen, and joins his group. Michael tells you that Rio has just checked in. You watch Michael flash a grin towards the small camera over the computer and type The computer returns with:

> **Welcome to the Oceans Learning Center, Michael.** You are in Mr. Phillips' discussion this morning, then you have time to work with your distant partners on the wetlands project.
>
> push return for more. . .

Michael: This computer lets the office know I'm here, and it tells us where we are supposed to go or what to do if we forget. But I already know what I am doing.

Quality Review Panelist: What if you type in the wrong code?

Michael: If the code doesn't match your picture, like, if you look into the camera instead of me (Michael leans to the side of the computer and types mml1), see what happens?

> I am sorry I didn't recognize you. Will you please type your name.
>
> Name:

See, it didn't work. We have to make sure we are signed in. That's our job.

Michael opens the cabinet below the computer and pulls one of the notebook computers out of the recharging unit while Barb continues the description of the attendance procedure.

Barb Milner: After the second bell rings, the computer displays pictures and names of any children who have not completed this check in. The guide or teacher only has to doublecheck for the missing kids and the attendance process is complete.

A round-faced, middle-aged man has left a group of students and is approaching you.

Carl Side: Welcome to the Oceans Center! I heard you might be visiting our Center this morning. Dave Brott asked me to tell you that he will be here soon to talk with you. Please look around and I will be happy to answer any questions. until he arrives.

Barb leaves you with Carl to meet the two center teachers, Noel Phillips and Marilyn Quinsay, and team teacher Dave Brott.

Carl Side: As you can see, some kids are still outside, others have checked in. I like to open the room as soon as I get here because I like the kids to see this as their space. They know the rules; if they are too rowdy, I just ask them to leave until the bell rings. It works OK. The students only have five more weeks until their exhibition and they are very excited about it. You can see their projects taking shape all over the Center.

Quality Review Panelist: What are they doing over there with all those tubes and pans?

Carl Side: The kids are experimenting with different ways to convert salt water to fresh water. And next to it are plants that can tolerate some salt in the water. One group of students is trying to figure out what properties make it possible for a plant to live in salt water and what happens to plants as the amount of salt in the water changes. That is why some of those plants don't look so great. These experiments are supervised by Dr. Hugo from the university. See the tall girl with the pony tail, that's Merica. Her group is doing the first part of a genetics experiment that will be continued all year by each of the teams. Over there, Rio's group is working on a play. See Vincent and Tamar? They wrote the play and are directing the younger kids, including Rio, whom I think you met.

Michael, seeing that your attention shifted to adult conversation, took the notebook computer to the nearest table and was now reading the screen. You wander over to see what he is doing. He has logged on to the server and is checking his mail. You apologize for the distraction and ask him to explain what he is doing.

Michael: I am checking my personal mail. You can't read personal messages during class time. See, here are project messages and this is my mail slot. During Center time, my personal mailbox won't open. I have to read mail before or after school or during our free times.

You ask Michael about the messages listed.

I am working with one of the biologists at the San Elijo Lagoon. They are creating preserves for the California least tern and the western snowy plover. Look, here are their pictures. Rio and I did some observation shifts at the site with binoculars over the break. See, we sent a message to Dr. Cooper recording our observations, but he hasn't written back yet. There are more birds coming now that their nests have been restored. We are studying wetlands, oceans and lagoons, you know, water, with kids in other places. But in my personal mail slot there are messages from kids. I have been sharing game hints with a guy in Alaska.

You leave Michael reading a message marked "Yea!!! Trek gold finally found" to see what other students are doing. Within a short time, a bell rings outside and the room fills with students who move through the Center with a sense of purpose. There are now more than 20 kids on the rug on the west side and Carl is reminding them that they need to keep their voices down. Mr. Phillips enters from the west side of the Center. Carl quickly introduces each of you. You learn that Mr. Phillips, one of Ocean Center's two curriculum coordinators, oversees the Humanities and Performing Arts strand.

Noel Phillips: Hello, welcome to our Center. I hope you had some time to look around. Did you see any of the student projects? If you get a chance, you should ask Tera's group to show you their multimedia display of the effect of the moon on the tides. They are doing a great job. They can also show you what would happen to the earth if the moon wasn't there. It is a pretty impressive presentation of their understanding. What I find so exciting about multi-media is not the presentations, but the fact that kids can work with their own understandings by creating their own movies, presentation and programs.[10]

Today, we're going to have one of our "big ideas" discussions. The students know that the whales will soon be visible off the coast. The question is—"Why do whales migrate instead of hibernate like bears?" Students have been asked to come with their hypothesis about why whales migrate, what factors would increase or decrease the whale migration, and why they don't hibernate. Students have time to explore the topic before we have a discussion. I encourage them to talk with parents or try to find resources in the NetWorld or from print or people resources. Then we share what we found out and what we think. The younger kids often ask the type of questions that push all of us to really understand the issue. To help answer tough questions, I check the National Teacher Online Resource List. You probably know about it; companies or businesses donate a few hours of employee time to respond to teacher questions. I found an email address of a research team at Scripps that will respond to teacher questions.[11] I can generally find someone who can help in any area. If you will excuse me, I have to get started. I just saw Dave in the office. He is the team teacher for these kids, and he said he will be on his way over in a few minutes.

Mr. Phillips walks to the far side of the Center and picks up a conch shell and blows into it. More students move to the rug area. He glances at the computer and sees that Ricky and Kalani are missing. Kalani's picture is dim which means her parents have already called in. No one has seen Ricky, so he pushes return and attendance is over. A programmed call is placed to Ricky's parents.

Reaching to the wall, Mr. Phillips flips a switch. There is a mechanical whir and what looks like a carpet roll drops slowly from the ceiling. It unwinds like a large projection screen until it reaches the ground separating the circle area from the rest of the Center. Then it slowly inflates to become a rigid wall, leaving only a small doorway. The sight and sounds of the student group are gone and the Center becomes smaller.

Meanwhile, on your side of the new wall, students are collecting small packs from one of the closets and talking about who will take what. Some kids are arguing about where the nets are, who gets to take the Batiquitos Lagoon CD guides, and which micro-sensors will need to be taken. Within a few minutes another teacher appears, checks the computer screen, and finds all

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[10] Recently George Lucas, renowned movie director, testified before the U.S. House of Representatives Subcommittee on Telecommunications and Finance on his ideas about reaching for a technology-enriched educational system of the future which he calls "Edutopia." He is producing several movies set in the future that will provoke teachers and student to envision the use of the multimedia tools in new ways. But the central thesis of this paper is that the construction of a vision and the work to implement it will need to be repeated by the students, teachers, and school leaders in each school. It is in the design process that is critical in constructing school reform. The George Lucas Educational Foundation (Box 3494, San Rafael, CA 94912) publishes information leading toward his vision in a newsletter called Edutopia. There is no cost for a subscription and it can also be found online (Gopher: glef.org; http://glef.org).

[11] There are many projects that are working on finding ways to connect subject matter experts to schools are resources. In the Passport to Knowledge project, on which I am currently working, television and telcomputing are used in parallel to take kids on electronic trips to remote "fields" of science. One component to these field trips is that the scientists agree to respect to questions that students have with responent to their scientific work. Trevor Owen has created "Electronic Writers in Residence" which connects professional writers with students through computer links to help them develop their voice through writing. Judi Harris, from the University of Texas in Austin, has been designing a project "Electronic Emissary" in which subject matter experts are matched with classrooms where there is interest in a specific area of expertise. Using the computer, these outside experts become both teachers and learners as they work electronically with students who share their interest. Recently on the Internet, research groups have offered services to schools like "Ask a Geologist" to field questions that student or teachers may have on issues related to the Earth. Similarly, a university professor has organized his students to provide an "Ask a Mathematician" service.

her students have checked in. Marilyn Quinsay is introduced as the Ocean Center math and science coordinator. After a quick round of introductions, she turns to her students.

Marilyn Quinsay: I assume that all of you have your data recorders, any micro-sensors you need, and your sketch pads. Your group should have a camera, binoculars, and their guides. The group leaders should have the data recorders and the youngest member should take the binoculars. (Then, turning back once more to the visitors). Too bad you don't have time to join us on our field trip, but I hope that you enjoy your visit.

About 16 students kids leave the room in groups of 3-5 students. Marilyn waves goodbye and reminds you that you will have time to talk later. This leaves a group of about 25 kids working around the different areas of the room. Carl makes the last check of the attendance chart, looks around the room, and then comes back to talk with you.

Carl Side: You just met our two Ocean Center curriculum coordinators. Let me show you around. The room to the right is our "lab," this central area has mostly tables and chairs, and the discussion room is now hidden by the wall. Teachers can decide which space is best for the type of lessons they teach. Inflatable walls make it easy to divide the space. The six ceiling-mounted monitors have replaced blackboards and display what is on the screen of the multimedia Center. If we have the whole group lesson, we separate these rectangular tables for more seats and use the circle tables and rug area. The teacher stands over there by the multimedia cart. The monitors make it easy for each student to see without crowding. If some students are not participating in the lesson, we can separate off the science lab area and they can work with me. The three multimedia computers are portable and can be moved wherever they are needed.

Quality Review Panelist: What are the rest of the students doing?

Carl Side: Different things. These kids over here are creating their own designs for desalination. And this group is examining a colony of fairy shrimp, a species that has recently made a dramatic comeback now that we are preserving more of the wetlands. (Looking toward a student standing alone at one of the tables and raising his voice slightly)—Eric, you need to use this time productively. (Turning back to you)—Sorry. They are following the work of scientists involved in restoring the Batiquitos and San Elijo Lagoons. Some students are working on individual learning contracts. Oh, perfect, here comes Dave Brott, he can answer your questions. I need to get back to the students.

Carl introduces you and then moves over to Eric's group. Dave explains the roles of the center staff.

Dave Brott: I'm not sure how much you heard about how we divide up responsibilities. I am the team teacher for all of the kids at this Center. Carl and I stay with this group evaluating their performance in different learning contexts and across Centers. We work with the Center teachers, who spend all year in the same Center organizing the curriculum and making project options available. Marilyn and Noel coordinate the participation of other teachers and outside experts both online and those that come to the Oceans Center. They are the "content experts" making sure that we have the intellectual resources to expand on and extend the academic interests of our students. But the trade-off is that they have fewer opportunities to observe student performance across settings. On the other hand, as the team teacher, I watch student performance across settings and find ways to encourage or motivate the students to take advantage of different learning opportunities in each Center. Together we provide a good balance between a rich learning environment and a personal connection with each students.

Dave gives a quick overview of the Center activities for the day and then the discussion turns to issues of student assessment. You want to know how learning is assessed.

Dave Brott: Assessment is what concerns most people when they see kids involved in group projects, especially kids of different ages. We have spent a good deal of time talking about *why and* *what we assess*. The result of our discussion is a different *process* of assessment.[12] The functions of student assessment are complex and some functions conflicted with our goal of promoting lifelong learning. We don't use assessment to sort students according to their "intellectual skill." We create multi-age groupings to avoid tracking students for success or failure at very early ages. Grades were used in the past to motivate students by creating an external reward. Extrinsic rewards are not effective and this can be seen by the fact that parents often had to find additional extrinsic rewards or bribes to motivate their children. Low grades can be very destructive. We find that creating a museum exhibit that is enjoyed by the community and provides more intrinsic motivation to learn. We think it is important for all of us, students and teachers, to know how we are doing. We try to encourage a sense of self-improvement through learning that we hope will become a lifelong habit.

Our past methods of assessment involved using student memory for content information to index learning. It was an easy but inaccurate measure. Now we use the intersection of three measures to assess student learning: self-assessment, community comments, and teacher feedback. Student performance on national standardized tests is used as feedback to the teachers.

So let me explain the process of student assessment. At the end of every session, the students spend time reflecting on their work as they get ready for the exhibition. They select their best work to display in the exhibition. But they also have to see how they measured up to the goals they set for themselves. I help them set realistic goals and then we all work to help them achieve the goals. So the first form of evaluation is the student's written reflection on their accomplishments and success in reaching the goals they set.

The exhibition provides a time for parents and community members to see what students have accomplished. Parents can see how their child's work compares with that of children of different ages and abilities. The exhibition provides students an opportunity to teach their parents. We ask our visitors to comment on what they see in the Center and to compare it to their expectations for learning. These Center assessments often provide a view into the work accomplished outside of school, in homes, and in the community.

The final measure is a "process" report from the Center teachers. Here is where technology has played an important role by providing an efficient way for our team to make, store, and share observations about students. Did you notice the clipboard that Carl was carrying? We all have one. See the microcodes by student names on this clip board? As I notice things while they are working, I make notes that are automatically added to their computer file. For example, from here I can see that Patrick and Kerwin are working on the measurement of a blue whale. Patrick is using the ruler and calculator with ease and finding the length and converting it to the scale we are using. He is also explaining it to Kerwin who is attending, but not making any of the measurements himself. So, I use this touch screen to scan Patrick's code, then the project name "fish scale," and then the code that describes his behavior. I can do the same thing for Kerwin. I can develop my own system of "benchmark" codes for different aspects of the tasks from academic to interpersonal issues. If I want to add a new comment, I touch here and then go to one of the Center multimedia stations and type the comment. If I touch a group code, the comment goes to each student's file as well as to the group file. Because the comments are codes, the students cannot see or tell from this sheet what notations I am making. This keeps the system very private. In fact, if I hand this to you, you will not be able to enter anything as I have to scan this microcode on my ring to use it.

[12] For more information of function of grading, see A. Kohn, (1994) "Grading: The Issue is not How but Why," *Educational Leadership* vol. 52, No. 2, 1994, pp. 38-41.

All of us have these clipboards but we don't use them all of the time. However, when we see something that we want to share with the team, this is an easy and efficient way to do it. Because of the ease of representation, we can use the information in many different ways. Marilyn might search for all comments that are related to the measurement task and look to see if a task is appropriate for an age group. I spend more time reviewing individual student profiles across different Center activities.

An advantage of this system is that any of us can note patterns among the comments. For example, if I notice that there are more comments about either boys or girls in one area, I can alert others and we make a point of watching the other group more closely. In the past, at report card time, there were always some kids who just slipped through the system because they escaped the notice of overworked teachers. Every week a printout identifies kids who have the least comments in an area and we all make a special effort to watch these students more carefully. We all try to make student observations as they happen because we know how quickly memory fades.

All student records are stored on the computer. You saw the kids check in. Their daily schedule is on the computer. Did you know that parents with access to the NetWorld can access their child's school schedule from their computers at work? This way they are better able to ask questions or follow the work of their child in school. If a child is giving a special report at school or practicing a performance, we sometimes have a parent who wants to watch from work. We can focus these small cameras on the students and parents can watch. Of course not all parents have this flexibility or access. Students can also bring tapes from home and make a copy so that parents can watch their child's speech or presentation later. These performances demonstrate student skills.

Quality Review Panelist: Does this mean that the parents can see the comments that you and the other teachers make about their child?

Dave Brott: No, not in real time as we make them, but eventually they will see a summary "process report" at the end of the term. I take all of the observations that are made on a student and organize them into a report card. I can display the frequency of different comments and create a picture of student strengths and weaknesses. Most of the time, comments across teachers are similar and I just create the report. But sometimes they are very different. For example, one teacher might appreciate the creative skill in humor, while another might define the behavior as disruptive. We meet as a group and come to a consensus on how to present these abilities. The process reports together with the exhibitions of student work give parents a clear picture of their child's school performance.

Each term, I compare process reports with student self-assessments. If they match, then we work out a set of goals and perhaps a personal contract for some work to be accomplished during the next session. If they are not in line, then I call for a parent/teacher/student conference to arrive at a common understanding of expectations and behavior. Students who are doing well have more freedom to explore areas they find of interest. In some ways, students earn their intellectual freedom. Giving students more responsibility for their learning seems to be the key that changed students. We seem to have many more "gifted" students than we did in the past.

School assessment takes place in the first part of September when we compare our students with students from around the nation on the National Standards Assessment Tasks.[13] You will be able to see these scores later in the office. Our students score very well in these tasks as the learning center structure help them take knowledge learned in one

[13] These don't exist now but I believe they are a reasonable projection from the current debate and work on creating National Standards. For more information see National Council on Educational Standards and Testing, *Raising Standards for American Education*, (Washington DC: U.S. Government Printing Office 1992.

setting and apply it other settins. The teachers use these scores to identify areas of concentration.

You and your team member move around the room reading the reports on the wall and looking over the shoulders of students. Most children are working on projects but some students are working with computer programs that look like math and language games. You ask one student what she is doing.

Student: I am practicing math facts—mostly times tables. I guess I take too long to figure things out, so Mr. Brott wants me to see if I can improve my speed. We can invent our own ways to solve math problems and I am real good at that, but Mr. Brott says I will be even better if I know these by heart. My personal goal is to get to under 11 minutes a race. I think these computer race car games are dumb, but I just broke 12 minutes so I think I will be fast enough soon, then I can get back to work on my project.

You watch for a few minutes, thank the student, and continue through the Center. Mary Stanley, the computer expert, enters the room and goes over to the multimedia computer in the lab area. She asks the students if they are prepared for their teleconference, reminding them that Dr. Noorg is volunteering to help and they need to take advantage of this opportunity. She opens the conferencing program and exchanges a few words with Dr. Noorg and then leaves. You can hear Dr. Noorg telling students that over 92 percent of the salt water marshes on the West Coast have been destroyed and encouraging them to see their work as helping to understand how to preserve these areas. Then a student from Oregon asks Dr. Noorg a question about the data they have collected. Soon one of the Oceans Center students is summarizing their work. Carl has moved nearby, available but not intrusive. Interested in the topic, you stay here for some time listening to Dr. Noorg and the student groups.

Your attention is pulled away by students coming through the small door in the temporary wall. Mr. Phillips is organizing students into small groups at the round tables with some materials. Within a few minutes another teacher enters and says something in Spanish and a dozen or so students follow this teacher into the discussion area where Mr. Phillips had been working earlier. But your attention is diverted by a low whistle from a student working with notebook computer. You want to know what he is doing.

Student: I am reading the research journals from Paul Smith, who is in Antarctica. He didn't send a message last week because they were lost on the ice for three days before they were rescued, sounded pretty scary. Now they are stuck in another storm. I'm glad I can do my ocean work in the classroom! [14]

Leaning over, you read the screen:

[14] This is part of a much longer message by Paul Smith shared on the Passport to Knowledge, "Live from Antarctica" electronic field trip. The students were able to follow researchers, pilots, weather forecasters, camera crew, a teacher, a 17-year-old student, as well as others as they set foot on the distant continent of Antarctica and began their explorations and work.

Last week I went south to Robbo's and had a fantastic time quadding around the islands. We climbed through icebergs, said hello to Weddel seals, climbed up to Opaque Lake (so called because the water is full of penguin waste) and laid hands on the Vanderford Glacier without an enormous chunk breaking off and squashing us. There are about 13 islands down that way and although we didn't get to all of them we covered a lot of ground. One place I'd like to go back to is Herring Island where the seals come to give birth in October. As is so often said about Antarctic weather-beautiful one day, really horrid the next--we were stuck in Robbo's hut for the next day with the strongest blizz recorded this year blowing outside. Angie read the hut log and found out how, in its early days, it had a tendency to snap guy ropes and move the hut several meters. It didn't this time but not for lack of trying on the weather's part. i thought I'd just open the door quickly and peek out. Bad move. Sort of like getting all your daily fresh air in about two seconds, plus a shower once the snow's finished melting..

Push RETURN

At that momenta small boxed message appears at the bottom of the screen from the school office.

Ms. Johnson, our parent/artist, will be here **in** five minutes to help students with the ocean mural. Those involved should finish up their work, log off, and gather their materials.

At the same time, Barb Milner returns to the Center and explains that for the next hour the students will all be in skill clinics of different types. This is the time when almost all teachers are in the Centers working with groups of students. You again raise the issue of differential skill levels and ask how this works.

Barb Milner: Using the assessment profiles from the beginning of the school year, students have areas of concentration identified. These can be areas of student expertise or areas of weaknesses. Students have individual goals and the skill clinics are organized to help students in these special areas. The composition of these groups is one of the continual topics of teacher discussion in our staff meetings. There is no perfect formula for balancing the comfort level of learners in homogeneous groupings with the challenge that comes from working with heterogeneous groups. Each group of Center and team teachers tackle skill clinics in their own way.

You stay and watch the lessons until Barb indicates it is time to visit the business complex. You would have enjoyed more time in the Center, but you also want to find out how this district made the transformation from the traditional hierarchy to this collaborative arrangement. You are intrigued by teachers who move in and out of the classroom so easily. One of your questions is how teacher unions and job protection issues are handled in this new arrangement. You follow Barb toward a modern structure of wood and glass as she describes its history. The other members of your panel are already there.

VISIT TO THE DISTRICT/SCHOOL OFFICES

Barb Milner: A professional career path for teachers necessitates a place of work other than a classroom or Center. So, we did some creative thinking and eventually sold the district offices. With some help from a bond passed by the community, we were able to build a smaller office site at each of the eight schools in the district. You saw the school planning office and the school secretary in our earlier meeting, but now I want you to see the rest of the office complex.

On the other side of the school planning office is a medium size office and a small workroom with office equipment, file drawers, and some video and electronic equipment including a large Silicon Image system. You meet Alan who is the office/district manager at Central. He works directly for Josie and handles district records. He introduces you to several other people working in the office.

Alan says they are mostly supported by grants and contracts held by mentor teachers.

You walk down a short hallway. To the right is a library conference room with a number of hardwood tables pushed together to form one large table and a set of padded office chairs. To the left you can see a lunch room with some people talking and waiting in front of a microwave. You walk past these rooms into a modern looking office complex divided into modular units. Room dividers create a number of different-size offices, some with doors open, others are closed. You are curious about who gets larger or smaller offices.

Barb Milner: (laughs) Well, it isn't always the easiest decision and it changes from year to year, but we try to be as fair as possible. Sometimes mentor teachers prefer to share a larger space among two or even three teachers because they are not here all the time. In some cases they are working on the same project, other times they are just friends who find it easy to share a large space. Other teachers would rather have a small space to themselves. Another factor is the nature of a project. For example, Marilyn Quinsay is working on a math multimedia program for Educational Designs. You may have noticed the Silicon Imaging System in the workroom? She uses a range of different tools that take up space so we give her more room. Her work makes it possible for us to have new equipment. We are getting a new touch screen system for the Center as a result of her contract. She is working with a national team of teachers and students to develop a multimedia theme-based curriculum. With the Silicon System, we can use the Custom Courseware Service to design and print classroom materials as we need them.

Quality Review Panelist: But who makes the decisions about office space?

Barb Milner: The actual decision is made by the teachers in our school management meetings. We meet face-to-face during each term break to make decisions that relate to teaching and working. But we have online interaction all of the time. We believe that teachers must have the responsibility for making the decisions that affect them. This is the way we deal with most issues of limited resources in our district.

Quality Review Panelist: Since you mention limited resources, I notice that some desks have computers, others don't. How does this work?

Barb Milner: Just like you saw in the Center, the notebook computers are charging *here (she opens the cabinet under a multimedia computer similar to the one in the Learning Center*). All teachers have their own private "card" drives, and of course space on the office network. But these notebook computers make it easy for us to share resources. Of course, we would love the new "Power Paper" computers with those "crystal image" screens, but we just don't have the funds to upgrade. I think it is the nature of schools to have to work with yesterday's technology but at least we have portable, cordless computers. During the heaviest use time, inter-term and term breaks, we borrow computers from the Centers.

Quality Review Panelist: Who works at those desks along the wall?

Barb Milner: Those open stations are primarily for the entry teachers. Since they spend almost all day in the Centers, they tend to keep their work and materials in a Center desk. But these open stations provide a quick place for anyone to check mail or type a letter.

Quality Review Panelist: I see phones. How many lines do you have and how do you account for phone use?

Barb Milner: There are phones on every desk, finally, but no, they are not private lines. In fact our limited budget still makes it necessary for teachers to have calling card codes and limits on the copy machine and printing supplies. The difference is that teachers set the limits and monitor themselves. When teachers get grants and contracts from different groups, they include indirect costs of 40 percent for phone, mail, and other office expenses. This is how we are able to maintain the office.

We are headed for the conference library to talk about staffing. Josie is waiting for us and I think

Table C-2: Teaching Positions

Instructional Positions	Academic Requirements	Average Time at this Level	Salary Range
Learning Guides	▪ 2-year College degree with a Learning Guide Certificate or B.A.	3-year renewable contracts, security of employment after second contract.	$20,000-$25,000/year $110/day
Entry Teacher	• B. A. and provisional teaching credential	Up to 5-year contract with tenure decision between years 2 to 5.	$25,000-$30,000/year $120/day
Mentor Teacher	▪ Full teaching credential ▪ Other certification or education will be necessary for some activities.	Advancement beyond a Mentor Teacher based on merit determined by peer-review process.	$32,000-$50,000+/year $175+Iday (unlimited)
Master Teacher	▪ Administrative credential and usually graduate degrees	This is the top rank of educator.	$55,000+ $235+/day (unlimited)

she will have some information that will help you understand some of the things you have been seeing. I will be at the school planning office and will meet you there later.

***You** say goodbye to Barb as Josie welcomes you. The topic of discussion is different roles, responsibility, and, most important, the costs of new staffing positions.*

▮ Teacher Roles and Salaries

Josie Rowe: I hope you enjoyed your visit to the Centers. Now we have more time to talk about the changes in the career path of teachers. There are two critical components that make our plan different than any that had been tried in the past. One is the use of para-professional learning guides and the other is the combining of outside resources with public funding. I am going to describe the teaching positions and pay scales (see table C-2).

Learning guides are para-professional positions. Learning guides don't require a great deal of academic preparation, but they need to have good skills in working with and motivating students. Basically we have two categories of people who are attracted to this position. Some young people who are looking for a way to earn money between college and graduate school find organizing learning for students an enjoyable break from studying. Some are considering a career in teaching or feel that some experience working with kids will be a good way to prepare for their role as parents.

Then we have another group that is generally older, some have had teaching experience. To be very blunt, they are not interested in the intellectual challenges that face teachers in our career plan. They just enjoy working with kids. You met Carl, right? He is terrific with kids. They take to him like the Pied Piper. He wasn't great at organizing academic lessons, but he gave life lessons that students rarely forgot. In the past, he ended up with a class of the most difficult kids in the school because he was so good at reaching them. But this was unfair to Carl who was overworked, and it was unfair to the students who did not have the same learning opportunities of other students. We were creating a school within the school, segregating students and not providing all students the learning environments they needed.[15] Carl decided he would rather be a learning guide than a teacher. He finds the work fulfilling and enjoys the freedom after school and during term breaks.

[15] Education tracking of students is not a productive strategy. For more extensive discussion of this issue see J. Oakes, Adam Gamoran & Page (1992), Curriculum Differentiation: Opportunities, Outcomes and Meanings, In: Philip Jackson (Ed.) *Handbook of Research on Curriculum (New* York, NY: Macmillan, 1992). Also see H. Mehan, Understanding Inequality in Schools: The Contribution of Interpretive Studies, *The Sociology of Educational vol. 65, No. 1, 1992,* pp.1-20.

Learning guides work from September to mid-July. During the one-week half-term breaks, they have meetings and recordkeeping tasks, but they get the two-week period between terms off. Their salary works out to about $13 per hour. They open and close the centers each day. They are in the centers or on the playground seven hours a day with a 45-minute lunch and a 15-minute break. But they do not have to prepare lessons, write report cards, or work on weekends. They are the only group in our district that is still represented by traditional teacher unions. However we are all members of the recently evolved American Education Association (AEA). We believe this organization represents the transformation that we are working towards.[16]

Quality Review Panelist: How do you react to the criticism that you are de-skilling the role of teacher? What if you just kept increasing the time kids spent with learning guides versus teachers? Does this worry you?

Josie Rowe: Yes, this does worry us and we have spent many hours discussing this very issue. But we try to look at the whole picture. We wanted to arrive at a system that included those who wanted a fast entry into working with kids, but also provided a system of rewards, a career ladder that would attract talented men and women into the challenge of continually assessing and evolving the best possible educational system. There are many teachers in other school districts with less skill than our learning guides who work with students all year. We are trying to *increase* the level of skill by not losing talented teachers to other careers. Because job opportunities for women have expanded, it is important to create incentives to attract the level of teachers that we want in leadership roles in education. Remember that learning guides are not teachers. They are there to supervise learning. Without teachers, there is no learning to supervise.

Our teachers did an analysis of how they spent their time in the classroom. They found that they spent an average of two-thirds of their time teaching either whole group or small group lessons but that there were 20-minute periods throughout the day when students were doing group work or individual writing or reading. Children, unlike older learners, cannot be left without supervision. The learning guides provide this supervision. But maybe this will be more clear after I introduce our different levels of teachers. There are entry teachers, mentor teachers, and master teachers—and there are levels within each rank.

Quality Review Panelist: My concern is that the daily rate you list for the different ranks of teachers looks very low, but you list a high yearly salary. Can you explain this?

Josie Rowe: Entry teachers are beginning teachers. In practice, most have full credentials, but they can be hired with a provisional credential and finish their credential work while they teach. Entry teachers are expected to spend five or six hours a day with students in the Center and the rest of their time is spent working with Center or team teachers. Entry teachers are paid during term breaks like learning guides, and they are also paid during half term. Except for a day or so of supervising student exhibitions and attending team meetings, they can structure their time during term breaks, but the expectation is that they are working during this time. They do have some vacation time, one week at Christmas and one week during the summer, but the rest of the time they are learning. It is their time to develop an area of expertise. The difference between a learning guide and an entry teacher is in *time* rather than *money.* Entry teachers have much more time for

[16] Trade unions were set up to protect the rights of workers from the abuses of management. Professional organizations are set up by members to set standards, control certification, regulate members and provide channels of communication. With a shift from teachers as workers to teachers as professionals should come a transformation of teacher unions to professional organizations. The American Education Association does not currently exist but represents this evolution that I believe is vital to educational change. The new organization suggests a shift to shared responsibility.

planning and for developing ties in the professional community of educators. It is these ties that will lead to professional work and pay.

The transition to a mentor teacher will be based on the productive use of this time. Over the first five years of teaching, entry teachers have almost a full year of professional development time. Entry teachers, like all teachers, have flexible control over their work. They can work in the school office complex, at a resource center or library, or at home. The normal career path has them come up for a tenure peer review in their fifth year. They are evaluated in a peer review process in terms of their teaching skills, their expertise in an area of their choice, and their service to the educational community. Entry teachers are encourage to develop professional ties but not to take on additional responsibilities outside of Center teaching. We believe it takes concentrated teaching for about three to four years to develop one's style as a teacher. Most entry teachers begin as "team teacher" because this gives them the opportunity to collaborate with three different sets of Center teachers over the year. While these new teachers are analyzing student learning, they are exposed to the teaching styles of our best teachers. This way they learn the skills both from center participation and observation. Team teachers prepare and teach lessons in close cooperation with center teachers.

Once a teacher has demonstrated good teaching skills, they are free to develop an area of expertise which will eventually lead to professional opportunities. We provide the time and encouragement for our teachers to pursue intellectual challenges outside of the Center. Since we did not have funds to pay teachers an increasingly higher salary for teaching, we have instead made it possible for them to essentially split a teaching position with other work in the educational community. We give teachers *time* to pursue intellectual challenges that we believe make them better teachers.

Quality Review Panelist: What counts as "an area of expertise" and how do teachers decide what to do in this professional development time?

Josie Rowe: That is a good question and some entry teachers find making that choice difficult because it is a new concept. But in our early discussions of what made someone an ideal teacher—remember, we talked about that this morning—we found that it wasn't the particular skill, like teaching writing, organizing innovative science labs, or integrating technology. It was more the very fact that these teachers had worked, often on their own time, to develop a strong passion for some way of improving education. It was this *process of learning*—not what they learned—that characterized our best teachers. So we wanted to develop a plan that would encourage teachers to be learners. And we wanted them to have a choice.

Of course, like most choices, the options available are somewhat constrained by economic realities and regional opportunities. The goal is to have this area of interest evolve into contractual work. If you decide to become a specialist in an area in which there is little need, such as a bilingual specialist in a language that is not spoken here, it is going to be more difficult to find work in this area. On the other hand, if there is grant money available for environmental science or district and state opportunities for bilingual Spanish/English specialists, developing expertise in these areas might make it easier to make the shift to a mentor teacher.

Mentor teacher positions are very different than traditional teaching positions. Mentor teachers are paid a slightly higher rate for classroom contact hours. But, again, the advancement to this level is a shift in the amount of time spent in the classroom. The expectation is that they will spend up to two-thirds of a day teaching. However the other one-third of their time is free for them to take on other tasks that are related to their developing area of expertise. These might be consulting contracts, district resource positions, foundations and government grants, or work at the university either in research or education. While teachers have written and received grants in the past, they have been largely for materials or salaries of other people. In our district, mentor teachers can write grants which include up to 50 percent of their salary.

If an entry teacher develops an area of expertise early and is awarded a grant or receives a contract, he or she can ask to be reviewed for mentor status after two or more years of teaching. At the other end, an entry teacher must develop an area of expertise within seven years or they will not have their contract renewed. Basically, we are saying that teachers are professional learners who want the intellectual stimulation that comes from following personal interests.[17] We have taken a strong stance in this district. We don't think someone can be a good teacher if they are not learning.

Ben Barrel (who enters the library to hear the last comment): And similarly, we decided that all school leaders should be "master teachers" as well as master learners. This keeps the loop between leading, learning, and teaching closely aligned.

Josie Rowe: Hi, Ben, I'm glad you have time to join us. I am describing the steps from an entry level teacher to a mentor teacher and then maybe you could continue with a description of the process of becoming a master teacher.

Ben nods as Josie continues with the description of mentor teachers.

Josie Rowe: A mentor teacher is in the Center working with kids for three to four hours a day, some more, some less, depending on lots of factors. Some of our mentors provide services that were in the past district positions. Our resource teachers help identified students intensely during inter-term weeks and sometimes between terms. This way students who need extra help are not losing regular instruction for their special needs like speech or language.

A mentor teacher is guaranteed a minimal salary for teaching two-thirds of each of the school days and participating in the three exhibitions. This leaves almost half their time for work in other areas of education, and more than half of a year if they choose to work over summer break. All of these work arrangements must be submitted and approved through our contracts and grants office, but it provides an open-ended salary for teachers based on achievement. Each of our teachers can choose how hard they want to work. Some of our teachers work year round using the term breaks to work on many exciting projects. They earn salaries that are comparable to other professionals such as university professors, lawyers, high-level administrators. Our district benefits from these arrangements in three ways. One, and most important, our teachers are intellectually engaged in educational issues which often enrich Center teaching. Two, the outside employment covers office and other "overhead" expenses which support our office complex. And three, we rarely lose our "best" teachers to jobs outside of the classroom.

Our district has one of the best records in the nation for pulling in grant money. This is not surprising since we provide time and incentives for teachers to write grants. Some of our teachers are partially funded by grants—in fact you might have noticed the group in the Oceans Center working with the vernal pool fairy and tadpole shrimp. Their work is part of Center teacher Noel Phillips's grant from the Wildlife Federation. I think some of the highest-paid mentor teachers have contracts with publishers designing electronic materials for home as well as education markets. Since up to 50 percent of a mentor teacher's salary can be negotiated by the teacher with other organizations, a mentor teacher could, in theory, earn more money than a master teacher. However, I suspect that this level of recognition of skills would prompt a review process and an early advancement to master teacher level.

[17] The professional development of teachers requires taking an active role in learning new ways of teaching. The change is more likely to happen if their professional development is linked to their career advancement in their chosen area of expertise. For more information on the multiple factors involved in professionalizing teaching, see W. Fireston & B. Bader, *Redesigning Teaching: Professionalism or Bureaucracy?* (Albany, NY: SUNY Press, 1992).

Quality Review Panelist: Is there an issue of travel? If teachers are working for people outside of your district, don't they have to travel to meetings?

Josie Rowe: While some of these projects involve travel, teleconferencing helps keep teachers on site most of the time. The rapid development in groupware has made it much easier for these teams and committees to work together. In fact, I personally feel more productive in online meetings, although I admit it is more fun to go and meet with people face-to-face. However, there is plenty of time between terms to arrange for travel.

I think I've said enough about mentor teachers, so I will stop and give Ben a chance to tell you how mentor teachers progress to master teachers. He might want to address the issue of travel as he has a 50-percent contract with a curriculum committee at the State Department of Education.

Ben Barrel: Travel is not a problem as most of my work is done online. In fact, most meetings are at conferences that I would probably go to anyway. But let me describe the master teacher position. The plan we have in place says that after five years of teaching as a mentor teacher, a teacher can request or be recommended for a peer review for the position of master teacher. Some teachers may not be ready after five years and that is fine. A mentor teacher can stay a mentor teacher for as long as he or she wishes. There is no pressure for all mentor teachers to be master teachers. Being a master teacher is a way to reduce teaching responsibilities to provide more time to pursue leadership roles in a wide range of educational settings.

You have to be at the rank of master teacher to be a member of the principal or superintendent teams. But master teachers don't have to be administrators. Because of the way we started, currently most master teachers have either principal or superintendent positions. But this year that will start to change. For example, Marilyn Quinsay is up for review. She has developed an international reputation as one of the leading developers of multimedia programs and she wants more time to work on this.

In the past, teachers such as Marilyn would have left teaching for the prestige and financial rewards of developing new materials. We give them the option to stay connected and involved with students. That is what I like about our plan. But I do have a concern. I am worried that if all teachers stay in education and become master teachers the work in the Center might become too fragmented. Right now we have an ideal mix of learning guides and entry, mentor and master teachers and things are working better than I ever expected. But I hope that this system will be able to develop along with teacher advancement.

Josie Rowe: Ben, you missed our discussion of learning guides and concerns of de-skilling the role of teaching. But I know these issues concern you.

Ben Barrel: Yes, we are charting new territory and it is difficult to see into the future. But we are hopeful that the creation of the Teacher Senate and the increased income to the school from master teachers will be one of the resources that gives us more flexibility in dealing with problems as they arise. The system is not fixed. We know that change is part of the plan and we are hoping that our new collaborative structure will be open enough to design this change. The excitement of our teachers in having control of their lives in the Teacher Senate is big step forward.

Quality Review Panelist: Well, I want to know how this system compares in cost to the more traditional plan of having one teacher for 30 kids. I can see that there are some savings with learning guides, but how many teachers do you have and what is the pricetag of your payroll? How is teacher-student ratio computed?

Josie Rowe: I have prepared a chart so that you can see how the number of teachers has shifted at this school. In 1995, we had about 30 students in a classroom with a total of 18 teachers

Traditional Model (1994)

Beginning teachers	Midrange teachers	Highest teachers
3 full-time	4 full-time	11 full-time
3x$25,000	4x$38,000	11 x$46,000
$75,000	$152,000	$506,000
3 teachers	4 teachers	11 teachers
TOTAL: 18 full-time teachers		$733,000

New **Model (using 1994 equivalent figures)**

Learning guides	Entry teachers	Mentor teachers	Master teachers
7 full-time	4 full-time	12 two-thirds time	4 one-third time
7 x $22,000	4 X $27,000	12 X $32,000	4 X $24,000
$154,000	$108,000	$384,000	$96,000
7 teachers	4 teachers	7.92 teacher equivalent	1,32 teacher equivalent
TOTAL: 20.24 full-time guides and/or teacher equivalents			**$742,000**

(table C-3).[18] The 18 classroom teachers were mostly at the top of the teaching pay scale.

With our new structure, it is difficult to make direct comparisons, because of all the differences. We have seven learning guides (one for each Center), four entry teachers, 12 mentor teachers, and four master teachers. The Center time for mentors and master teachers (two-thirds and one-third) is an average and in practice it is different for specific teachers. This gives us, counting learning guides, the equivalent of more than two additional teachers, which changes the student-teacher ratio from 30.5: 1 to 26.9:1. The payroll difference is not significant given this reduction in student-teacher ratio.

Quality Review Panelist: So, in table 3 you have only listed the money that mentor teachers receive for teaching. But they essentially have other jobs that add to this salary?

Josie Rowe: Yes, some of the mentor teachers combine Center teaching with work as resource specialists in a particular area of expertise. These positions were covered by district funds and the cost also remains about the same. Instead of one teacher working across several schools, these resource positions are held by mentor teachers who are at the school all of the time. They often have the benefit of knowing much more about the students they work with since they see many of them in regular Center teaching.

Other teachers developed expertise outside these certified school or district positions. Some of these are funded out of public education funds, such as Courtney Balboa who supervises student teachers for the university. Also, I think we have two mentors working with the State Department. Is that right, Ben? (Ben nods.) Two or three are participating in research projects and testbed activities that are funded by a combination of government and foundation money. And then we have a few that work with commercial firms, mostly creating classroom materials. The most difficult part is trying to keep up with the developments in the lives of all of our teachers and organizing lessons and professional commitments into a single system. I would be misleading you if I said this system always works smoothly. But we feel the benefits far outweigh the extra scheduling work.

[18] For the sake of this comparison, all salary estimates are based on monetary values of 1994. The salaries listed for the traditional model are drawn from the California Statewide 1992-93 Average Salaries and Budget Percentages for School Accountability Report Cards. I have also consulted with school district superintendents and school principals to assure reasonable figures.

TABLE C-4: 1994 Administrative Salaries	
Salary for Superintendent	$100,000
Salary for two Assistant Superintendents ($78,000 x 2) =	$156,000
Costs associated with School Board	$60,000
Salary for eight Principals ($66,000 X 8) =	$528,000
Total Cost	**$844,000**

Quality Review Panelist: For the master teachers, your chart shows only $24,000 which I assume covers one-third of their time that they spend teaching. How are master teacher salaries covered?

Josie Rowe: Yes, that is a good question and that leads into these other two charts which I have prepared to compare our district administrative costs to the past. Table C-4 shows our 1994 administrative costs.

Table C-5 shows how things look in our current arrangement. I have subtracted the teaching salaries for master teachers as this amount is covered in the teaching budget in table C-3. You can see that our administrative costs have remained more or less the same.

Quality Review Panelist: I see that you subtracted the costs associated with the school board. I read somewhere that you don't have a board. Don't you value community input?

Josie Rowe: We do! So much so that we wanted to find a way to strengthen it, but we didn't believe that a school board, as it operated in 1995, was accomplishing this goal. The school board was set up in the early part of the last century to make the schools accountable to the public. The problem was that, in practice, school board members did not always have the background in education to provide the level of leadership that was required. Each newly elected board had be reeducated. The more serious problem was that the school board members had almost no links with the community they represented. They made decisions as individuals and few people in the community had any idea of what was going on in the schools.

Too often, well-intentioned people ran for school board because they were concerned about a single, controversial issue. But a school is a complex system and any attempt to solve a single problem without a systemic understanding of the educational community causes problems. Every two years our superintendent and her assistants struggled to educate a new panel of citizens so that they could make critical decisions that affected the lives of teachers and students. The problem with this model was that our school leader became a school board tutor working overtime to educate five people. This was problematic in two ways. These five people had limited channels for gathering community input. And we needed the time of our superintendent to work with teachers to provide leadership and direction. Most of us felt strongly that if we were going to have the leadership that was necessary to be constantly evolving, the decisionmaking power needed to be in the hands of our teachers and not hastily trained outsiders to education.

We actually do have a school board but it has changed in name and function. The decisions that used to be made by the board are now made by our "Teacher Senate." Each teacher at our school, regardless of level, has one vote in the Teacher Senate. The voting takes place electronically. This way our superintendents work with teachers to create the best quality program possible. But I don't want to ignore the issue of community leadership in education. We have arranged a luncheon

Table C-5: 2005 Salary for School Leadership	
Five Master Teachers/ Co-Superintendents (4x **$82,000)**	**$ 328,000**
16 Master Teachers/Co-principals, two per school, (16 x $65,000)	+$1 **,040,000**
Total	$1,368,000
Master Teacher (one-third) teaching salary ($2400,00 x 21 Master teachers)	$ **504,000**
Total	**$ 864,000**

over this topic because we are absolutely interested in keeping the community highly involved in all decisions that affect their children. As you will see, our community is entirely behind our decision to put educational decisions in the hands of experts.

Quality Review Panelist: How would you describe the benefits of your changes in teacher's roles and responsibilities?

Ben Barrel: Well, the teachers here are alive with passionate interests and they have time and support to pursue them. When they teach, they teach from what they are learning. It is fresh and they are not bored. In fact, I doubt that you will find anyone, teacher or student, who uses "bored" to describe what they do here.

Quality Review Panelist: I did find one child who said that a computer game she was working on to reinforce the times tables was boring. But in some ways it supports what you said because she was eager to return to her project work, or at least that's what she said.

Ben Barrel: All right, I probably do overstate things a bit (laughter). But I am sure you see the excitement that all of us here feel. I work with excellent school leaders from all over the globe using telecommunication to explore new ideas. And I bring that excitement and the ideas back to inform my work with teachers and students. I often share ideas that I learn with students when I teach. And I learn so much about leadership from listening to students. I think the students enjoy being part of the design. They know that they are partners with the opportunity to exchange ideas with everyone in our school community.

Co-Principal Nancy Broyles had entered the room and been listening. She joins in the conversation.

Nancy Broyles: I find having a principal team has helped us make tough decisions. This is my second year. This shifting responsibility within a partnership keeps us from either changing things too drastically or becoming too fixed in a single way to accomplish a task. Since any master teacher can represent our school, there are more people to be on those endless committees and task forces and to be present at school functions. I can now have dinner with my family on at least some weekday evenings. Ask any principal outside of our district how many times he or she makes it home for the evening meal!

Quality Review Panelist: What if a master teacher becomes too busy to teach?

Josie Rowe: Master teachers must teach at the very minimum the equivalent of one hour a day. But this does not mean that a master teacher has to teach every day. One of our district master teachers does televised teaching and tapes all of the segments in one term. We can teach summer school, but we have to spend some time teaching the age group we serve. That was one of our Charter District arrangements. I really enjoy my teaching.

Nancy Broyles: By the way, mentor teachers also have this flexibility. That's the headache in scheduling we referred to earlier. We try to balance the requests of the teachers, but we also have to make sure that all of the Centers are well staffed with teachers who are skilled in the appropriate areas. In the classroom arrangement, the principal used to spend so much time sorting kids into classrooms and responding to parents' complaints about placement decisions. Now the parents are mostly content because the student teams cycle through all of the teachers. The strain now is to balance all of the teacher requests. But, like before, things have to work out and they do.

Josie Rowe: An important difference is that we can support each other informally. If I have a meeting to go to and it is scheduled for a time when I am teaching, I can check with one of the Center teachers and just trade times or days. With more people, there is so much more flexibility. I remember my days as a classroom teacher when you couldn't go to the bathroom without causing staffing problems.

Well, I can see that our lunch has arrived and also members of our community advisory boards. I think we can shift to the topic of community leadership and involvement.

Parent and Community Interactions

At this point, a number of people enter the room and a buffet lunch is set up on one side of the room. As we bring our lunch to the table, Bill Parks (in a fire fighters' uniform) is introduced as the chairperson of Central's School Community Council with Amelia Leff, Bud Porter and Lensci Denny as council members. Dee Sharp is Central's representative on the District Community Board. Josie excuses herself and leaves while Ben and Nancy stay and Barb rejoins the group.

Barb Milner: Welcome and thanks to all of you for being here. Our guests have heard that we have a different model of community involvement. They know about our community exhibition but we haven't said anything about Central's Community Council. Bill, I am going to let you talk about this group.

Bill Parks: Sure, Barb, I would be happy to. Our Community Council is a combination of our former PTA and school site council. We meet three times during each term to discuss schoolwide issues. We form study teams to think about ways to solve different school problems and ways to support our Center teachers. One of our tasks is to circulate information before the exhibition and to prepare community feedback forms for each exhibition. Because so many of the people in the community come to these presentations, we use this opportunity to get parent and community input on issues that face our schools. This way no one person or group has the say about what the "community" thinks. Teachers have worked very hard to be responsive to our collective positions.

Dee Sharp: Our District Community Board works in much the same way. Each school community elects one person to serve on this committee. These elections are done during our exhibitions at the end of the year. Council members have much less decisionmaking power than school board members did in the past. Their role is to provide community input to the district Teacher Senate. One important service we perform after every exhibition is to collect the information from each school and publish a summary of results in local newspapers.

Amelia Leff: One of the things we do as part of the council is to encourage all community members to come to our exhibitions—even if they don't have children. We want them to see the school as their school. Everyone needs to be involved, not just parents. Some of the students take their presentations to hospitals and convalescent homes for people who find it hard to come to the school. We post signs and banners in stores and banks and CD rental libraries inviting everyone to come to school. We have found that our community is more willing to support our schools and vote for school bond issues if they visit the Centers and see how hard students work with such outdated equipment.

Dee Sharp: The Centers are a wonderful source of public education. They are like evolving museums with exhibits designed by kids. I really like learning with my kids, and I feel so much more involved when I see not only what my child is doing, but what teachers, other experts, and other kids are doing. I always look forward to the exhibitions. And I like seeing kids learning outside of the classroom in our community.

Amelia Leff: Our community council has also taken the lead in solving a long-standing problem. Kids out of school without parent supervision became a problem about 30 years ago when unpaid "homemaking" mothers moved out into the paid workforce. Some kids went off to organized preschool programs, but many kids were left in empty buildings. So, over the past few years, we set up an after school community program on the school site. We passed a bond to help with initial costs. Basically, we created a contractual agreement between the city and schools to work together to provide a community after school program. Then we scheduled a number of classes offered by people in the community. Some are routine like scouting and sports, but we added different options including clubs for hobbies like reading, chess, gardening and kite making. One of the parents designs unusual kites and sells them worldwide. She offered to work with students for an hour a week.

The most controversial issue, which I think is finally worked out, has to do with religious education. We understand the recent Supreme Court ruling to mean that religious education can be held on school grounds under the following conditions.

1. Religious instruction is a parental choice and other options are available.
2. Teachers are not involved in the religious training because of students' strong emotional attachment to their teachers.
3. All religions are given an equal opportunity to provide classes.
4. All expenses other than the use of school buildings are covered by the religious group.

So, we have about 10 different religious training courses. There is also a values clarification and self-esteem program that is funded by the Coalition for Religious Education in Our Schools. This is an organization of all the religious groups. They felt it was important to offer a non-denominational discussion of basic social values for children whose parents do not want religious education but would like their kids to think about difficult social problems.

Bud Porter: I just wanted to add that one of the benefits of this program is that many of the students who in the past were segregated in religious schools are back in public education. This makes our community more integrated. This option deflated the effort to resurrect voucher initiations that took money away from public education. The effect on overall school climate has been great. And I think it is great to have such an extensive after-school program provided by the community. Community services are so much more effective than police in reducing crimes.

Bill Parks: And, there are other class options. Some have more expenses associated with them so we ask parents to donate the cost of supplies, but we don't exclude students. We have inter-school teams and tournaments in jump rope, track, soccer, and basketball. Students can take classes to learn to be referees. And we have Science Olympiad training classes for intermediate students during the spring to prepare a team for this regional competition. This has been run by parent volunteers for seven years now. Also, Planned Parenthood offers a course called "Our Bodies and Ourselves" for our 11- and 12-year-olds. The school library/media center is open and Friends of the Library sponsors storytelling and craft programs for our younger students. On our stage there are often "dress rehearsals" and kids in the library program serve as an audience

Quality Review Panelist: Who provides all of the teachers for these clubs?

Dee Sharp: As you might guess, it involves a coordination of the efforts of a number of groups. The city pays small teaching stipends for teachers. Some teachers hold special education classes during this period and these are funded with federal money. All religious education classes are paid for by their congregations. Some programs have community sponsorship. For example the Seaside Botanical Garden Society is sponsoring the gardening club and mostly retired people help kids learn these skills. Some of the other clubs, like Science Olympiad, are run by parent and teacher volunteers. The coordinator for the service component from our high school arranged to send about a dozen high school students to each of our schools each afternoon. Most of the high school students come on a once-a-week basis over the year, which fulfills their service requirement. They provide supervision for our sports tournaments and some coaching in both sports and school. We don't charge for any of the programs but we do accept donations and many of our parents become sponsors of a club or program.

Quality Review Panelist: How many students participate in these programs?

Bill Parks: Usually about 80 percent of our students stay on any given day, but I would venture to say that most kids are in some program. The kids who do not stay are usually kids who are involved in community programs that we can't offer at school, like swimming, gymnastics, club sports, or other activities.

Quality Review Panelist: How do you deal with the issue of equipment and classroom materials being taken or destroyed?

Dee Sharp: This was one of the biggest problems in past programs, but we've had less trouble. I think it's because kids see it as school and they respect property just as well as they do during the rest of the day. Students are used to moving around and working in different spaces. For many students, the program is just part of the school day. The computer equipment locks into those recharging units you saw. The biggest concern is always damage to kids' work and we deal with that the same way we do during the day. We want kids to learn to respect the work of others. I think it helps that we know exactly who is in which room each session so that there is some accountability. Overall, we've had fewer problems in this area than we expected.

Bill Parks: We are pleased with our success and we are constantly considering new ideas as well. At every exhibition we show what we have accomplished and ask students, parents, and community leaders for their input on how to make the school better. Right now, for example, we are exploring an idea for programs during term breaks. There has always been federal money to provide special tutorial work for "at risk" kids and some special education programs. But we are working on plans to provide inter-term opportunities for all students, like our extended community school program, maybe on a sliding scale for cost.

Barb Milner: So, I hope this makes it clear that while we don't have an elected school board making education decisions as in the past, we have found other vehicles for keeping us connected with the community. This gives our educational leaders more time to deal with pressing school problems and we feel that these open exhibitions make us publicly accountable to our community.

Quality Review Panelist: I guess I would like to know how you managed to get such a vibrant community effort going.

Amelia Leff: I can respond to that because I think I have been involved in this school the longest. My son is now in high school and comes back as part of his community service. I just consider it my community service to stay involved and I enjoy it. But, you ask how we got from a detached school to this new arrangement where the school is "central" to our lives.

I think the first step was when teachers starting to teach integrated themes and they did not have enough resources. So they appealed first to parents and then to everyone in the community. Then in 1994 we received one of the "Service Learning" grants and the kids moved out of the classroom and into community projects. They started producing information sheets and newsletters that were available in stores and banks. Then I think we started to move our displays into the community. Our small airport let us use their hallways for our public education campaigns. Once the kids had a purpose, they were more geared into learning. And this relationship with the community continued to grow as teachers pulled more of us into the classroom and the kids took more of their learning out to the community.

Lensci Denny: Here is another example of this service learning. One of our teachers, Clare Devlin, took a survey in a local senior citizen organization about what their members would like to learn about computers and specifically what applications interested them. Then she had her students learn how to use these programs so they could teach them to the seniors. For one month the seniors were invited to come to the school and learn from the students. This program was very successful. But what Clare never realized is what a powerful resource the seniors would be to the classroom once they were computer literate and interested in what was going on in the school. They have contributed in so many ways, both in time and money; they gave us a big thrust forward.

So, an attempt to help this others ended up helping us. And I guess that is how it went.

After more discussion, the lunch is cleared and the community representatives leave. The review panel returns to the school planning office to look over school records, student performance scores and tests, and other documentation. The test scores show a steady climb in averages but lots of student variation. Barb describes how some students who have done well in the past because of good memories are taking longer to adjust to this new way of demonstrating their thinking.

Later in the afternoon, you meet with the entry and mentor teachers. They reinforce the same story that you had heard all day. Everyone has more time to engage in teaching and learning. One of the mentor teachers is explaining why this is so important.

Michel Lickte: The most significant difference from the past is that we have time—time to think, time to reflect, time for collaboration with others making the important decisions that set the stage for learning. Most of us had an “area of expertise” before these changes, but we had to develop it while teaching full-time and we rarely received the recognition or encouragement to really pursue it. Being able to retreat to the office and make professional contacts during business hours—this is a rare benefit for teachers. And the school offices are a great place to work, I really enjoy working with other teachers on projects. The changes have encouraged an entrepreneurial sense to professional development which many of us have found very rewarding.

Sandi McCan: I love teaching but I also enjoy my work testing, reviewing, and editing materials for School Media Tools Service. And I enjoy doing this work in the evening at home. I teach between 9:00 and 12:00 and between 1:00-2:00. Since I have extra time during the day, I sometimes help a child who needs some individual help. And I am not the only one. We all have much more flexibility now that we don’t have to be with the students all day. I can’t tell you what a sense of freedom I feel when I have all of my students working on some project and I can just leave the room knowing that the learning guide will supervise student work. Since my work involves testing new curriculum, I sometimes teach special classes making it possible for scheduled teachers to work with smaller groups.

Clare Devlin: In contrast, I like getting here about 5:00 in the morning and working in the office for about three hours. I have a grant to explore lifelong learning which helps me bring the seniors into the school. I am working on an article about our project. Sometimes I stop by the Senior Center on the way to school. Like Sand, I really enjoy the freedom to be at the school and not always in the classroom. I can come in here and just talk with other teachers. We have planning meetings and workshops during school hours! And I don’t mind filling in for other teachers or even helping out in the office, especially working with Marilyn. I have learned so much about computer graphics that I think my next project will be doing something with her.

Quality Review Panelist: How would you characterize the most significant change that has taken place in your charter district?

Hernando Borja: I know how I would answer that. For me it is becoming part of a vibrant community working collaboratively in the learning centers, at the school, and in the local community and across the country in the educational community. The collaboration is intellectually satisfying to me and to all of us. It provides many more opportunities for quality learning. We are all proud of what the students are accomplishing in the learning environments that we have created together. The rewards are collective rewards. In the past, there was always a bit of competition among teachers about who was the “best” teacher at a grade level, who had the best classroom. Parent requests caused so many conflicts as we tried to place students in individual classes. But in this arrangement teachers as well as students work and learn from each other. The multi-age teams are working very well—kids are more supportive in helping one another learn as there is not the underlying assumption that everyone in a team should already know something. We have always know that teaching is one of the best forms of learning but it was much harder to arrange for it to happen naturally in traditional classrooms. But in the centers, *teaching and learning* are part of almost every interaction.

And the other part of this is the shift in the relationship between teachers, principals and superintendents. The decisions that effect our schools and our work as educators are made by us in the Teacher Senate. We are all asking ourselves about what we can do to improve education and we all have a say in the answers to this question. We are more concerned about creating a shared vision then following the education ideas of a charismatic leader. The design of this school district is *our design* and that is what makes it so powerful.[19]

Quality Review Panelist: How would you evaluate the role of technology in the changes that have taken place?

Mary Stanley: As Central's technology coordinator, I can respond to that. The tools that we have, and the new tools that are available each year, are incredible. But they are tools and we need to know how to use them to accomplish important educational roles. In some ways, we no longer even think about the role of the technology separate from the activities because we are beginning to take it for granted. But I think Hernando just gave the answer to your question. Access to information resources in the Net World has been extremely helpful, and we have a better match between our teaching objectives and supporting materials. But the most significant change is the ability to work in groups with educators who share similar interests or face similar challenges. Everything from teacher senate decisions to student group projects are facilitated by our communication tools. I can say, without a doubt, that the rich network of human resources is the most significant technological advancement we have.

The meeting draws to a close. You are impressed by the strong sense of professional respect the teachers have for themselves and one another. The Teacher Senate is more than a symbolic step toward teacher responsibility for education. The teachers themselves convey the feeling that their advancement in the field of education is unlimited.[20]

[19] The view of the school as a community with self-management by professional teachers is an ideal that many would like to see as reality. T.J. Sergiovanni, in his book *Moral Leadership: Getting to the heart of School Improvement* (1992) (San Francisco, CA: Jossey-Bass, 1992) advocates replacing strong centralized leadership in education and with collaboration communities. Collaboration is time consuming and it is different to implement a high degree of teamwork without changing the existing dimensions of the role of classroom teaching.

[20] "You" is used in the plural in this paper to refer to two different groups, those who have read the paper and those who will read it in the future. Many of the statements and questions of the review panelists have come from this first group of readers and I am grateful for their comments and suggestions. For those of you who have just finished reading the paper, I would enjoy reading the report of your Quality Review Panel. What did you think of this school and school district? Where do you suspect that they will run into problems? What are the strengths of the program, and what policy recommendations would you offer to them? If "you" want to write the Quality Review of Central School, or of the Pacific School District, I would enjoy reading it: Margaret Riel, InterLearn, 943 San Dieguito Drive, Encinitas, CA 92024, (mriel@weber.ucsd.edu).

Appendix D
Year 2005: Using Technology to Build Communities of Understanding

D

Digital information technology is changing how people learn, teach, work, and play. By the year 2005, the capabilities and the affordability of digital technology could catalyze and facilitate the wholesale transformation of education and the communities that support it. SRI International's Center for Technology in Learning believes the effective use of this technology could alter the relationships between homes, schools, and workplaces and in so doing assist the creation of new kinds of communities (29,32). In this paper, we offer one vision of these new communities—communities that have learning and teaching at their core and use digital technologies to foster higher levels of community participation, enable deeper levels of cognitive and social engagement, and structure new kinds of relationships that support education. We analyze the social, pedagogical, and technological trends that support the realization of this vision, and we discuss the implications for teacher training, school accountability, and equity.

A community is a collection of individuals who are bonded together either by geography or by common purpose, shared values and expectations, and a web of meaningful relationships (33). In the communities that we envision in this paper—what we call "communities of understanding"—education is the common purpose, learning is highly valued, and a high level of academic achievement is expected of students and their schools. Mutual respect, honesty, and fairness are basic values, and there is a common dedication to see that each member of the community strives and succeeds. These values are enmeshed in the everyday activities and relationships of community life. There is a strong social network in these communities and a high degree of commitment to and involvement in the educational endeavor. This commit-

by

Robert Kozma and Wayne Grant

Center for Technology in Learning
SRI International

ment is shared by students, teachers, parents, and other members of the community. Although this description may seem utopian, many of these qualities characterize successful learning environments in inner-city public schools of choice, Catholic schools, and Asian schools of today (5,17,35,37).

Clearly, these qualities can exist in a community, independent of advanced technology. And there can be communities based on geography rather than values or on values different from those described above. But in our vision for the year 2005, digital technologies are used to create a web of relationships, engagement, and participation that transforms the educational enterprise and makes it the center of community life. Today, schools, homes, and workplaces function separately—connected by geography and circumstances but infrequently by common purpose and collaborative action. But in our vision of communities of understanding, digital technologies are used to interweave schools, homes, workplaces, libraries, museums, and social services to reintegrate education into the fabric of the community. Learning is no longer encapsulated by time, place, and age, but has become a pervasive activity and attitude that continues throughout life and is supported by all segments of society. Teaching is no longer defined as the transfer of information, learning no longer as the retention of facts. Rather, teachers challenge students to achieve deeper levels of understanding and guide students in the collaborative construction and application of knowledge in the context of authentic situations and tasks. Education is no longer the exclusive responsibility of teachers but benefits from the participation and collaboration of parents, business people, scientists, seniors, and, of course, students of all ages.

How can technology support this transformation? First of all, the emerging information superhighway (18,38) will connect schools with each other and with homes, businesses, libraries, museums, and community resources. The connections between schools and homes will help students to extend their academic day, allow teachers to draw on significant experiences from students' everyday lives, and allow parents to become more involved in the education of their children and to have extended educational opportunities of their own. Connections between school and work will allow students to learn in the context of real-life problems, allow teachers to draw on the resources of technical and business experts, and allow employers to contribute to and benefit from the fruits of an effective educational system. Connections between schools, homes, and the rest of the community will enable students to relate what is happening in the world outside to what is happening in school, will allow teachers to coordinate formal education with informal learning, and will allow the community to reintegrate education into its daily life.

To make these connections pay off, this infrastructure will be filled with effective and engaging materials and tools that challenge students, afford new activities, and motivate learning. When users access the superhighway, they will find rich, multimedia resources in mathematics, sciences, and humanities and rich contexts of authentic situations and tasks. They will have access to tools that allow them to communicate and collaborate with others, consider ideas from multiple perspectives, express their ideas in multiple ways, build models, and explore simulations.

As important as digital information technology is to our vision of the future, we have deliberately avoided the temptation to become overly technocentric and speculative about cutting-edge developments. Because we have chosen to limit ourselves to technologies likely to be in wide use in 2005, our scenarios of the future are actually quite conservative on the technology side. The technological capabilities we describe are fairly straightforward extrapolations and amalgamations of the capabilities available today in advanced systems, which we believe will be affordable by schools and homes in the year 2005. No doubt, the cutting edge of technological capability will have advanced beyond those presented in the scenarios that follow.

Rather than emphasizing cutting-edge technology, we stress the collateral social change and educational reform that must occur for this transformation to be realized. To realize the full impact of digital technologies on our educational system, there must also be massive changes in the larger social structures, relationships, and interactions within which the education system is embedded. The forces constraining educational transformation are not technological but pedagogical and social. Where we have been daring with this paper is in developing a vision in which many of the educational, social, and equity issues facing our country have been addressed in systemic and positive ways. In our analyses, we describe the needed social and pedagogical changes that can support and be supported by the emerging technological developments. When advanced technology is integrated into a broad effort for school reform, then educators, students, parents, and communities will have a powerful combination that can bring necessary, positive change to this nation's educational system (21).

Our optimism is tempered by an acknowledgment of all the earlier technological revolutions that failed to change the classroom (10). On the other hand, our enthusiasm is buoyed by a growing number of policy discussions, community experiences, and educational experiments in social, pedagogical, and technological change at local, state, and national levels that seem to suggest that our visions are not outside the realm of possibility. Nonetheless, what we present is our *vision* of communities of understanding; it is not a prediction. We do not assert that this will happen, only that it can and should.

With that introduction, welcome to the year 2005.

A VISION OF THE YEAR 2005

Characters (in order of appearance):

- Steve Early, a 14-year-old African-American.
- Nelson, a 17-year-old living in South Africa; Steve's electronic pen pal.
- Carmela Zamora, 15-year-old of Philippine descent.
- Mr. and Mrs. Zamora, Carmela's parents.
- Valerie Spring, a senior teacher with a science degree.
- Sharon Gomez, a mathematics teacher.
- George Shepherd, an apprentice language arts teacher.
- Christopher Lindsay, a school-work coordinator.
- Lynda Lucero, a 13-year-old of Hispanic descent.
- Mrs. Lucero, a design engineer at the Global Car Company.
- Vincent Tracy, 14 years old and visually impaired.
- Other children, parents, and community members.

Settings: Some of the events take place in children's homes. Most of the events take place in the McAuliffe Learning Center, which serves as the physical locus for formal learning, community activities, and social services. McAuliffe is divided into a variety of spaces specifically designed for technology-supported learning. Facilities include learning-team pods, each with a workstation and project resources (microscopes, fabrication materials and tools, etc.); small-group meeting rooms, each with collaborative technologies, a flat-panel display, and personal interaction devices; multimedia production and editing suites; and a large multimedia auditorium and performance center. These resources are used by students and teachers during the day and are open to community members and groups at other times (see box D-1).

Social Perspective: Connecting Learning to the World

An important motivation for learning comes from membership in a community. The meaningfulness of a learning activity is increased by relating events that happen in the larger world to things that are happening in the student's world. The need to understand these events and do something about them creates a context and a motivation for learning. Connecting the informal experiences and learning of the outside world with the formal learning of the classroom makes the knowledge

BOX D-1: Scenario One: Connections to the World

As he does every morning, Steve Early eats breakfast in front of the teleputer. While he watches a news program m one window, his personal communication service relays a video message from his South African friend, Nelson, m another window. Nelson's vid-message is about a train derailment near his hometown that caused a huge hazardous-fuel spill, made people sick, and now endangers a wild-animal preserve. Nelson explains. "I am afraid the chemicals will poison our water and hurt the animals " Steve clicks on a button that Nelson embedded in the message and activates a "knowbot." This software agent presents the news story as it originated m Nelson's community and then goes off to search for additional information about the train accident on the GlobalNet. After Steve checks out the Net pointers, he constructs his own agent to search the local and national video news servers for other stories about the accident He Instructs his agent to find video clips that run less than three minutes, sort them chronologically, and store them on the school server so he can access them later, As he finishes his breakfast, Steve watches the video that the agent retrieved.

Meanwhile, another student, Carmela Zamora, is flipping through channels to the Hispanic MTV-News and hears about the South Africa train derailment. A budding naturalist, she is alarmed by the news and wants to do something to save the animals. When her dad comes in to remind her about getting off to school on time, he sees the news and they talk about it. Carmela shares her concern and asks, "What can we do to keep this from happening?" He tells her, "We all have to help. The telecourse I'm taking is to learn a new manufacturing process that will make the rail cars my company builds stronger and less likely to crack open if they are hit or fall off the tracks Maybe you'd like to come to the plant sometime and see how they're made "

Walking to school, Carmela meets Steve and asks whether his South African friend knows anything about the accident. "Yeah, he's worried. It happened close to his town, " he says In the playground, they meet up with three other members of their Iearning team, the Falcons. This morning, they must present an idea for a project to their teaching team. Carmela launches in, "I saw a report on the news this morning about an accident in South Africa. There was a fuel spill from a train near a wild-animal park I want to find out what can be done to save the animals. " "Me too, " Steve says, "My friend Nelson lives nearby, and I watched some video clips this morning that we could use. Let's ask the teachers if we can figure out how to stop hazardous spills from hurting the environment. "

The other three students agree. In the project planning room, teachers Valerie Spring, Sharon Gomez, and George Shepherd and the five students gather around the teleputer and open their project planning tool. Valerie Spring starts off, "OK, let's fill in the goals for the project. What do you kids have in mind?" The students chime in with their ideas.

"Your ideas about reducing hazardous spills sound interesting, " Ms. Spring responds, "but what would you Iike to do about it? What would you like to accomplish with your project?"

"1 would like to find a way to keep hazardous waste from hurting plants and animals, " Carmela replies.

"1 think we should get a law passed that makes tank cars safer, " says Steve.

"My dad's company is working on that, Steve. Maybe we could talk to him about that, " she says

"1 think that's a good idea, " says Ms. Gomez Always looking for a way to bring math into he conversation, she asks, "What other kinds of things might reduce the risks connected with transporting hazardous wastes?" Carmela puzzles for a moment and then offers, "In addition to making tank cars safer, what if we reduced the number of cars needed to transport fuel?" Steve adds, '(I wonder how many car loads of fuel are delivered in a year. " Excited by the prospect of a solution, Carmela volunteers, "What if we Increased the efficient use of fuel by 10 percent?" "We wouldn't need as much fuel, " Steve replies.

BOX D-1: Scenario One: Connections to the World (Cont'd.)

"Wouldn't it also reduce the number of cars on the tracks?" asks Ms. Gomez. "if we reduced the number of cars, wouldn't that also reduce the chance of accidents?"

"Yes, and it would also make the air cleaner, " Carmela shouts, "Let's think of ways to increase fuel efficiency"

Hanging on the wall is a large, color, flat-panel display for plotting the project. The use of pointing devices with the display makes it easy for students and teachers to rearrange the software symbols and objects that represent their developing ideas. Working with the display and the software planning tools, students and teachers develop the project's organization, timeline, and goals, as well as each student's learning objectives and tasks, As the discussion progresses, the teachers check the goals that students suggest with those Iisted in the curriculum. They also look at learning-history profiles that show each student's current knowledge in terms of the goals. The tool lets them see the skills, activities, and subject matter that past projects have emphasized The teachers suggest activities that will help the students gain the skills, knowledge, and experiences identified as absent from their learning profiles.

For example, in her planning tool, Ms. Gomez Indicates that the new project will help the students strengthen certain mathematical skills and concepts, including measurement of liquid volumes, graphing number relationships, and making mathematical connections to real-world problems. She also Iists science facts, skills, and concepts appropriate to the project, including thinking critically and logically about the relationships between evidence and explanations, understanding ecosystems and organisms, and describing transformations of energy. Like most of her colleagues, Ms. Gomez has become adept at thinking in terms of broad, ambitious goal statements established by her school and district.

As a result of the discussions, the students decide to make an interactive multimedia report as their final product "You need to think about your audience for the report, " comments Mr. Shepherd, their language arts teacher, "and what they would want to know about your topic. "

"We need to think about why our report would be important to them, " adds Steve.

"If someone dumped fuel in your backyard, you would want to know how to stop it, " replies another team member. "Maybe we should show what happened to Nelson's neighborhood and then look for spills in our neighborhood, too, " adds a fourth member.

"But we need to find a way to stop it, " demands Carmela.

The students decide they will interview Steve's South African friend Nelson and ask his schoolmates to collaborate with them by gathering video images and other local information about the train accident that can be integrated with the information they create. They will also talk to community members in the McAuliffe neighborhood and see whether there have been any fuel spills in the area during the past year. Finally, they will come up with some suggestions for how to stop fuel spills. They will store their report on the community video server and make it available through the community-access cable channel and send it to Nelson and his South African classmates. The report will conclude by taking viewers to the Environment Chat Room on the GlobalNet, where they can talk to scientists, environmentalists, and others about the problem and potential solutions.

Each student has an assignment and downloads the project plan into a personal digital assistant with a beginning set of pointers to resources both inside and outside the neighborhood. "1 think we might really make a difference here, " Steve says. "1 can't wait to tell Nelson. "

acquired more useful and the world outside more comprehensible.

Technology helps motivate learning by bringing the world into the learning environment and increasing the authenticity of learning activities. Today's technologies—television, telephones, computers, electronic mail, and videodisks----offer ways of infusing real-world issues into conventional, discipline-based curricula. However, the usefulness of these technologies is limited by a paucity of interactivity—there is not much the student can do with this information. As technology evolves during the next decade, a host of personal communication and information services will become increasingly understandable, affordable, and accessible to consumer and education markets.

An interactive connection with the world can dramatically increase learning resources. Teachers and students can get access to expertise and information not otherwise available. More importantly, students can *do something* within this technological environment. They can interact with and influence other people. They can explore far-off continents, and they can add to the contents of far-off libraries. They can share a museum visit with their schoolmates or take a field trip without getting on a bus. Scientists can come into the classroom, and students can go off into space. They can identify people with similar concerns and find others who can help them solve their problems. This interactive web of people and resources can become a foundation for building the community of understanding.

Pedagogical Perspective: Project-Based Learning

In recent years, consensus has evolved around a set of National Education Goals to improve student learning. By the turn of the millennium, the individual states and local school systems are likely to implement these goals into an extended set of standards that students must achieve (for example, see references 6 and 7). These will serve as a focus for the design of learning environments and activities. Prominent among the National Goals is the objective of increasing student ability to solve problems and demonstrate competency over challenging subject matter, particularly in mathematics and science. In our vision, the "learning project" is the mechanism used to accomplish these goals.

Project-based learning involves students in the identification of some problem or goal of personal or group interest and the generation of activities and products that will accomplish the goal or solve the problem (4). Within this framework, students pursue solutions to nontrivial problems, ask and refine questions, debate ideas, design plans and artifacts, collect and analyze data, draw conclusions, and communicate findings to others. Because they bring problems in from their own personal lives, students are more motivated to pursue a deep understanding of a cluster of topics across related domains. This approach contrasts with the current practice of superficial coverage of many topics in a single domain.

The project is also a way of valuing and integrating knowledge from multiple perspectives and multiple disciplines. Naturally occurring problems are not compartmentalized into mathematics, science, and language arts. Furthermore, problem solutions benefit from the multiple expertise, perspectives, and modes of expression that come from multiple members of teams—both teams of students and teams of teachers. No one person is likely to have the solution to complex, real-world problems, and differences among students in expertise and experience are valued.

Project-based learning, particularly projects that emerge from student-identified interests, makes planning and accountability more complex. The challenge for teachers is to begin with these student-generated interests and guide the development of a particular project to make sure that students are challenged and that they accomplish important educational objectives. They must build on individual strengths and accommodate the individual needs of students within the group. In addition, they must work with students to generate productive activities and provide them with access to useful resources.

Technology can help both teachers and students manage the complexities of project-based learning. In the scenario above, teachers and students use project software to help them keep track of student progress with respect to curriculum goals. Teachers use the software to support students in structuring their projects by providing students with access to resources and activities they can use to accomplish their goals. And students benefit when they externalize their ideas by representing them explicitly as concrete objects with which they can interact more easily. Finally, both teachers and students can use the environment to share experiences and resources with others.

Pedagogical Perspective: Scaffolding

"Scaffolds" are external aids that provide cognitive and social support for people new to a task or knowledge domain, much as scaffolds on a construction site support workers and materials while a building is erected. These external aids consist of questions, prompts, or procedures provided to students that more knowledgeable people have internalized and provide for themselves. By performing part of the task, scaffolding allows students to manage tasks that are more challenging than the ones that they could do on their own (41). When these aids are a normal part of the classroom discourse, students can model these skills for each other and get assistance from the teacher and others in the group (25). As students refine and internalize these new skills, the supports are gradually withdrawn and students perform more of the task on their own.

Problem solving and critical thinking are particularly challenging curricular goals for young students. They must learn to analyze problems and specify goals, identify information and plan activities that will help them solve the problem, identify the products of their work and specify criteria that will be used to evaluate them, and work as a team to accomplish their goals. The use of scaffolding helps students work through these cognitive and social processes. By using these processes repeatedly across projects, students will come to generalize them, take them out to the real world, and apply them to problems they encounter there.

In our scenario, students use a combination of technological and social supports to scaffold their problem solving. They use a computer-based project tool along with the guidance of teachers and each other to design and manage their project. The tool and the teacher team scaffold students' work by stepping them through the planning process, asking them to define their goals, prompting them to select activities to accomplish these, guiding them to resources, and structuring their assessments. Students begin to use these prompts socially with each other, and ultimately the skills become internalized and they can use them on their own. While students work on their project, the tool keeps their goals and plans visible so that they do not lose track of them while in the thick of their activities.

Technological Perspectives

In this scenario, a number of technological tools and software utilities support student learning and connect it to the experiences, resources, and people in the outside world.

Computer-Based Planning Environment

Although pedagogically appealing, project-based learning and scaffolding present new challenges to teachers and learners. Teachers need help to ensure that open-ended, bottom-up, project-based approaches provide a comprehensive, balanced education, and learners need help in planning and executing their projects. Technology can provide this help.

Embedded coaching systems and intelligent critics that assist users while they are actively carrying out their tasks are beginning to appear in commercial products (for example, Apple Guide in Macintosh System 7.5) and will become much more common in learning software environments in the next 10 years. These approaches are particularly effective for open-ended exploratory environments (14) that emphasize the discovery process as well as project design and development. These software coaches and critics will provide timely curricular support for teachers, and, along with the teachers, scaffolding for students.

In this scenario, teachers and students use a project planning tool that helps provide students with guidance and feedback on the design, development, and execution of their projects. By constructing a "learning-history profile," or model of each student's current knowledge state, the project planner functions as an assessment tool that enables teachers, students, and parents to see areas that past projects have emphasized, as well as the objectives a student might address in the current project. In the process of constructing their project plan, the students and teachers work with the tool to decompose each activity into its constituent curriculum objectives. The tool makes suggestions for improvements to the project by referring to similar cases and draws from a database of activities known to have been successful in the past. A record for each activity in the database contains a description of the activity, a set of links to useful content, and a list of technologies these students will need to use to meet their learning objectives. Over time, the use of such tools, in the context of project-based learning, supports deep engagement in problems and content without sacrificing the comprehensiveness of the curriculum.

Integrated Personal Communication Services

Current approaches for exchanging electronic messages assume that users send, receive, and store messages within a single information utility (such as the on-line services CompuServe or America Online). These electronic communication services are separate from services for communicating by voice and from other information services, and these differences create difficulties and barriers for users. Several trends suggest significant changes by 2005 that will integrate these services, and make them easier to use.

For the past few years, telephone services have expanded to include voice mail (voice messaging) and personal telephone numbers (unique addresses). The telephone companies are increasing the capability of their infrastructure to transmit text and high-quality audio and digital video, and, as a consequence of recent FCC rulings, they are beginning to offer these services on a limited and experimental basis. Similarly, trends in the cable television industry suggest that, besides video-on-demand, cable providers plan to offer message services and access to the kinds of databases currently carried by information utilities. Despite the falling through of the proposed TCI/Bell Atlantic deal and the failure to pass federal telecommunications reform legislation, the complementary capabilities of communication companies continue to make them attractive partners (1,36), as witnessed by the recent Intel/AT&T deal to develop services for corporate video phones (39). Extrapolating these trends, it will not be long before an array of familiar consumer products can be used to send and receive digital messages in a variety of forms with a variety of devices at prices similar to those currently charged by cable providers, telephone companies, and other information utilities.

In this scenario, when Steve checks the personal communication service on his television for vid-messages, he does not leave the television experience and go to a desktop computer to enter a communications mode in a different medium (that is, text). Because of windowing and multitasking features offered by his “teleputer, “ he mixes the informational perspectives Nelson sent him from South Africa with those available from his local news service. These capabilities allow him to more seamlessly intermingle South African perspectives with local ones and to connect these perspectives with other information available in the system. Nor does Steve have to interrupt the train of thought he developed during his news viewing experience to log on to an information utility. The integration of services frees the cognitive capacity normally used to operate different systems and allows a deeper engagement with the ideas contained in the messages.

Smart Mail, Intelligent Agents, and Programming by Example

As a result of the integration of information and communication services, the amount of information and the number of people available on the network increase dramatically. Tools will be needed to make this mass of information useful and usable. Smart mail, intelligent agents, and programming by example will increase the power of communication, decrease the difficulty of finding and using information, and make the system easy to operate.

General Magic has recently organized a consortium of companies—including Sony, Motorola, Apple Computer, AT&T, Philips, and Matsushita—to develop personal communicators and advanced communication software and services to be offered at prices geared to the average consumer. The heart of these services is a communication-oriented programming language called Telescript. In Telescript, each message is an agent, or a "knowbot." The agent is a small program that can perform functions besides just expressing a text message, such as searching, collecting, organizing, and distributing information to certain people at certain times. In the future, scripting languages like Telescript will enable users to add computational capabilities to their messages (27).

For this technology to be broadly successful, the ability to construct a smart message cannot require a user to learn a difficult programming language or write lines of code. New approaches are simplifying this task by allowing users to "write" a program by example (11). In programming by example, a software agent monitors a user as he or she performs a task, such as constructing and sending a message. The agent forms a model of what the user is doing, and once it is "confident" that it understands the process, it will offer to carry out the actions in the future. Thus, by simply performing a task, the user creates a program that the system can implement under similar future circumstances. By 2005, such approaches will be so evolved that users will be able to construct agent scripts so naturally that they will be completely oblivious to the fact that they are "writing" a program.

The "smart" message Nelson sent Steve includes a set of computer scripts, which, when triggered, link Steve to more information. Nelson wanted Steve to see the train derailment and chemical spill from a South African and other perspectives, so in his message he included a hypermedia link that Steve can follow to see the South African news clip and an agent that Steve can activate to search for information about the train accident on the GlobalNet. Steve also constructs his own agent to search for and organize additional information of a certain kind. Construction of this agent is easy because these are the kinds of things Steve usually does with information, and the agent knows that (see box D-2).

Social Perspective: Connecting Learning to Work

Society is recognizing that students must be better prepared for productive jobs within the competitive world market and that those skills and knowledge could be better obtained if academic work more closely resembled authentic work. Reports such as *America's Choice: High Skills or Low Wages!* (24) rang the alarm that the United States is not providing an education that prepares young people for productive careers in the technology-dependent and highly competitive 21st-century work environment.

School-to-work transition programs should help students acquire the conceptual underpinnings of the skills they learn without becoming trapped in training on specific procedures or equipment, much of which will be outdated by the time the students enter the adult work world. Ideally, students should be exposed to both the practical contexts and the meaningful tasks of adult work as well as the conceptual knowledge and generalizable skills normally associated with formal learning (31). The teacher guides the transfer of knowledge between these two areas and helps students reflect on their experiences.

With this approach, students should be challenged by tasks that:

- Have analogs in adult work, but also reflect students' interests.
- Are complex and open-ended, requiring students to work through the definition of the problem and regulate their own performance.
- Relate to practical situations so that experiences from work and daily living provide important information, strategies, or insights.
- Can be accomplished in multiple ways, typically with more than one good answer or outcome.
- Are performed by student teams, with different students taking on different specialized roles.

BOX D-2: Scenario Two: Connections to Work

Later that day, Carmela and Steve join one of their other learning teams the Cheetahs which is designing a car to compete in the National Cyberspace Derby against cars created by students from other communities around the country, The team is preparing for the regional competition; the winners compete in the national finals. Students are coached by school-work coordinator Chris Lindsay and math teacher Sharon Gomez, Chris Lindsay starts the meeting: "There are two designs you folks have been working on; we need to decide which one we will use to compete in the regional, "

"Lynda and I want to race our fastest car, " explains Vincent Because he is visually impaired and cannot see the car being designed, Vincent relies on auditory and tactile feedback provided by the computer system, As he traces his hand over a flat-panel display, the system provides auditory information about the coordinates he is interacting with, He has learned to use this information to build an image of the car in his mind At the same time, graphic and text information is fed to a Braille printer so he has documented information that can be used in the future and shared with other blind students, "I like this design, " he says, "Now that we have modified the spoiler and tuned the manifold, this should be the fastest, "

"Remember, the race rules state the best overall car wins, " replies Ms. Gomez, "What other factors do you think you need to consider, given that rule? What might the judges include in determining the best OVERALL?"

Carmela responds, "Well I've been thinking about a new hazardous-waste project that Steve and I are working on, and I think building the most fuel-efficient car will be safer for the environment "

'(Yes, and thinking about it from a business view, what about the cost of production? You do need to make a profit, right?" offers another team member

With these ideas in mind, the student team consults with an engineer who works at the local office of Global Car Company, an automobile manufacturer and one of the race sponsors, The engineer is also the mother of team member Lynda Lucero. For weeks, Ms. Lucero in person and remotely responds to students' questions as they encounter problems with their designs, The students use a high-end workstation and computer-aided-design (CAD) program supplied by Global Car, The students' CAD tool has all the basic features of professional design tools but runs on less powerful and less expensive computers than the one in Ms. Lucero's office. However, the two machines are connected so that the same image appears on both screens and can be altered by both the students and the engineer,

- Are performed with the same information and the same kinds of technology tools (though not necessarily identical tools) that are used by professionals.

Networked communications and collaborative software can be used to create new relationships between work and school. As reflected in this scenario, teachers and experts from various professions can jointly design realistic activities based on authentic tasks that motivate the learning of generalizable skills and concepts. Teachers provide an overall structure, assess student work and create ways for student self-assessment, and point out linkages between project activities and the concepts under study. Mentors work with students on specific tasks, providing guidance and assistance when students reach an impasse, modeling the way practitioners in the field solve problems and providing guidance that is not associated with the grading process. All of this is supported by the electronic infrastructure and a set of software tools.

Pedagogical Perspective: Modeling

There are two meanings for the word *model* (15)—an "of' meaning and a "for" meaning—and

BOX D-2: Scenario Two: Connections to Work (Cont'd.)

Ms. Lucero's image appears in a small window in the corner of the screen next to the large window that displays a wire-frame model of their favorite design. Back in her office, she uses her stylus to lower the roof line on the model, and the students see the results on their monitor "If we make the roof line lower, it looks better and it will reduce friction—or what we call the drag coefficient—which results in increased fuel efficiency, However, manufacturing a sleek racing car can be expensive, and you have a limited budget for your design, This is what your teachers mean when they talk to you about 'constraints' in design. You are going to need to think carefully about whether to spend that money on a better engine, a more comfortable interior, or reducing the drag. " The team discusses these and other complex issues with Ms. Lucero.

The cars the students create are not static drawings but functioning models that they can test on a simulated cyberspace race track. So after they make changes to their cars, Ms. Gomez has the students conduct simulations to test each change scientifically by running the car and studying the effects of their changes on speed/fuel consumption comparison graphs. To increase their understanding of the issues, working with Ms. Lucero, she introduces them to velocity and acceleration graphs. The students begin to see that there is a lot of math and physics as well as artistic talent revolved in making a car that is attractive, fast, and fuel efficient,

At the end of the mentoring session, each student uses a personal digital assistant (PDA) to record new information and knowledge and a reflection on the day's activities in a "learning log, " Meanwhile, as they work with each Iearning team, the teachers use their PDAs to keep track of new skills the students have demonstrated and their impressions of how well the exercise fosters collaborative skills.

"OK, team, " Ms. Gomez announces, "everyone please put a note in your PDAs so you'll remember to have the people in your family conduct a simulated test drive of the prototypes by next Monday You'll need their comments on how each car handles. Ask them to compare each design to the cars they drive Remember, customer satisfaction counts, too. "

"The race is just two weeks away, " Mr. Lindsay reminds them. "You must decide on the final design by the end of the week so there's plenty of time to prepare your multimedia reports and rehearse your presentations. You will have to explain why you designed the car the way you did, Remember, we've invited families and neighbors to watch the race, so you need to be sharp. "

both are relevant to new pedagogical approaches. In the first sense, models are constructed, symbolic artifacts that simulate the "real thing" in some important ways. These artifacts may be scale models, flow charts, or computer simulations that display or operationalize the structural or functional relationships of a physical system, such as a mechanical device, or of a conceptual system, such as Newton's laws of motion. By building, manipulating, and explaining the design of such models, as illustrated in the scenario, students come to understand these structural and functional relationships (42). When modeling a phenomenon, students must represent their understanding of the world in an explicit way, as the students did with their design of fast, fuel-efficient cars in the scenario above. By representing these phenomena explicitly, students may uncover weaknesses in their understanding that they can work to correct. If students operationalize their understanding in computational models, they can compare the behavior of these models with the behavior of real-world phenomena, using these to judge the validity and reliability of what they know.

In the second sense, a model is a symbolic representation of something that is intended to become real. In this sense, behaviors, practices, and attitudes are modeled with the intent that students will come to be like these models. In cognitive apprenticeships, an expert carries out a task so that students can observe and understand the processes that are required to accomplish the task (9). This modeling requires the externalization of cognitive processes and activities that are usually performed internally. In the scenario above, Ms. Lucero was modeling how designers think, solve problems, and use their tools. In demonstrating the process by using the shared CAD tools, she not only modeled the use of the tool but the decision processes and procedural knowledge that are used to design cars.

Technology can be used to help make these internal processes external and observable while students are working on their authentic task. As well, the system can keep track of students' processes and make these traces available to both student and mentor. These traces can become the focus of cognitive mentoring in which both students and mentor examine the thinking processes behind specific decisions. Thus, the students' thinking processes themselves, as represented in these traces, can become a direct object of mentoring.

Pedagogical Perspective: Collaborative Problem Solving

Traditional school learning emphasizes individual achievement and solving problems without the aid of other people or resources (28). Although this approach works when learning facts and solutions to simple, contrived problems, it is insufficient for the application of knowledge to solve the complex problems of the adult work world. In the real world, complex problems are frequently solved by teams of people who bring to bear a variety of perspectives and expertise. Preparation for this environment involves learning to collaborate and to use a variety of tools and resources.

Collaborative learning focuses on problems rather than topics and engages students in activities where they produce and promote theories, interrelate ideas, and explain how things work or how they are caused. This shifts the pattern of discourse from teacher-initiated questions, followed by student responses and teacher evaluation, to a pattern of teacher- and technology-supported discourse in which students initiate inquiries, provide responses, and evaluate each other's contributions. That is, the focus of education shifts from teaching to learning.

Technology can be used to structure and facilitate this collaboration. Currently, there are several technology-based learning environments that illustrate this capability. Scardamalia and Bereiter's (30) computer-supported intentional learning environment (CSILE) is structured so that the students use a computer to collaboratively build a text and graphical database of information on topics of mutual interest. In creating this database, students engage in electronic interactions in which they pose problems, ask questions, and share their understanding. Pea (26) provides a graphical simulation environment with which groups of students construct ray diagrams that replicate actual or videotaped experiments illustrating principles of light and vision. White (42) designed a simulation environment with which students formulated and tested hypotheses about force and motion. Environments such as these, and the CAD environment in the scenario above, when used along with appropriate educational activities, transform the roles of students from recipients of transmitted facts to active participants in knowledge-building communities.

Technological Perspective

In this scenario, the school's computers provide processing power sufficient to render and manipulate CAD graphics and run simulations. The software enables students to create powerful project documents quickly and easily. In addition, the collaborative software, coupled with a broadband network infrastructure, makes school-work mentoring a reality. These capabilities enable new relationships, new levels of participation, and new activities that support connections between school and work.

High-Performance Workstations

According to “Moore’s law, “ the density of computer chips quadruples every three years. This trend is expected to continue until the year 2000, when extrapolation suggests that a single memory chip will store 256 million bits. The 256-million-bit figure may be slightly optimistic, however, since Meindl (22) predicts that growth will slow down sometime in the near future. Using Meindl’s projections, the density of chips will grow at 20 to 35 percent per year through the year 2111. If that trend—and a similar trend of increases in processing speed—holds, computers developed and priced for consumer and education markets will be able to process data at speeds approaching 400 MHz by 2005.

While power and speed quadruple every three years, historically computer hardware prices drop by half. Following similar trends, prices of RAM and VRAM will continue to fall and enable learning environments to upgrade workstations so that they can render and manipulate detailed graphics images at speeds greater than those afforded by today’s dedicated graphics workstations. Additionally, the cost per megabyte of storage will drop to enable storage systems for low-end workstations to reach into the gigabytes.

Consequently, in this scenario, students use what would be considered, by today’s standards, a high-end graphics workstation to develop their cybercars. These students and teachers take advantage of this processing power by working on authentic and appealing car design problems to learn physics and math.

Compound Documents

Supported by trends in object-oriented programming, software developers are moving away from current applications-centered models of software development toward document-centered approaches. Applications-centered models focus on separate task clusters, like writing or budgeting, and design software with functionality that corresponds to these clusters, such as word processors and spreadsheets. This model assumes that users enter a task mode (such as writing) and will need only the functionality pertinent to that mode, as narrowly defined. Therefore, a user who wants to add pictures and sounds to a document must move back and forth between several other software packages (such as a graphics or sound package) and deal with the operation of these other programs.

Document-centered approaches assume that users will want access to different tools all the time. Thus, document-centered approaches encapsulate functionality in software components that users can access within any document. For example, instead of working with a word processor, drawing application, or spreadsheet, users can work within generic documents and import into those documents the specialized capabilities needed to perform specific tasks. This capability will make systems easier to operate and tasks easier to perform. As with integrated communications technologies, a document-centered approach frees the cognitive capacity normally used to operate different systems and allows users a deeper engagement with their ideas.

In this scenario, document-centered approaches enable students to easily import dynamic modeling capabilities into their designs, so that their cars can actually race in cyberspace. They can also export components of their design document into their multimedia report document, so that they can demonstrate design features as they present the rationale for their design.

Simulation and Modeling

The opportunity to model a phenomenon offers students a significant new way to represent and operate on their understanding of the world—in this case, a world of cars, what makes them work, and how they are designed. Document-centered approaches enable students to import “smart objects” from a car design object suite into their project document. The objects themselves “know” how they can interconnect. And because these objects are fashioned in view of an overall model of how cars operate, when interconnected they can contribute to critiques of students’ evolving car designs. These objects also “know” about properties of the world in which cars operate.

Consequently, when students carry out simulations, they receive feedback about performance and efficiency. For example, in this environment, students can even carry out wind tunnel simulations, which, with the help of visualization, enable them to assess the aerodynamic efficiency of their designs. Thus, the technologies that support modeling constitute a learning environment that involves students in a systematic process of recursive design—a process that requires them to construct a grounded understanding of physics and math while simultaneously developing a mental model of systematic inquiry.

Collaborative Computing

Currently, researchers are focusing a great deal of attention on workgroup computing, also known as groupware or computer-supported collaborative work environments. These are hardware and software environments that connect people, perhaps at different sites, to work on shared tasks. These environments allow users to exchange and work on shared documents, in synchronous or asynchronous mode. The connections may provide for the exchange of formatted files, voice messages, graphics, or video. The environment scaffolds collaborative problem solving and design. Computer-supported cooperative learning environments are just beginning to spin out of these technological developments (26, 30, 31).

Because they have access to collaboration capabilities, when students in the scenario above reach a stumbling block in their approach, they can connect to a car design expert who shares their document space. Ms. Lucero not only sees the design that the students are creating, she can manipulate this design on her workstation. The students can see and hear Ms. Lucero and see what she is doing with the design, and they can work together on its development. The collaboration environment also records a history of the group’s design, so that Ms. Lucero can see earlier versions of the design and review the design process. The expert collaborates with students to solve special problems that teachers do not have the expertise to tackle, and she collaborates with teachers to create authentic tasks and experiences for the students. In this way, the technologies enable new kinds of relationships and new levels of participation that can support learning.

Assistive Technologies

Advances in computer and other technologies have long offered the potential of enhancing the education of children with disabilities, and in the past decade, many applications of software, computer peripherals, and other technologies have been developed or adapted to increase the participation of these youngsters in learning experiences. Because of the increasing awareness and acceptance of disabilities in our society, and the rapidly accelerating pace of technology development, we foresee an increasing range of assistive technologies by the year 2005.

The full range of children with disabilities who can benefit from technologies is too broad for us to address in this paper. For this reason, in our scenario, we have selected just one area on which to focus attention—visual impairment. Currently, there are a number of assistive technologies designed to help persons with visual impairments. They include fully speaking, hand-held dictionaries, screen readers with audio feedback that allow the user to get an audio “dump” of a computer screen, Kurzweil readers, Braille printers, and so on.

In our scenario, assistive devices designed for the visually impaired and specialized interfaces for technologies used by his fellow students enable Vincent to share his learning experience and reduce the isolation his disability imposes. For example, students with no visual impairment might be using a graphical user interface (GUI) to interact with the software; Vincent would use speech recognition technology and an interface that uses the same graphic metaphors but presents them in words (40). In addition to recognizing his speech input, the technology provides Vincent with the same information that others can read on a screen as text or graphics. This can be done by translating this information to voice, so that Vincent can hear what is on the screen instead of seeing it. In our scenario, we have also projected that Vincent could use a touchscreen to enable him to visualize graphics or schematics, the information being provided to him by voice according to the coordinates that he touches on the screen. These powerful assistive technologies not only increase the participation of disabled students but provide students with environments of equivalent experiences that enable new relationships between disabled students and their nondisabled friends (see box D-3).

Social Perspective: Connecting Learning to the Home

A key factor in building "communities of understanding" will be the extension of learning environments to include home and parents. Although most parents want to be involved in their children's education (13), a number of factors make this difficult. The rise of single-parent and dual-career families has reduced the amount and flexibility of time that parents have to assist their children and communicate with teachers. Some parents are inhibited by cultural differences, feelings of mistrust, or their own lack of education. Unfamiliar curricula and recent developments in knowledge make it difficult for some parents to draw on their own education to help their children. As a result, parents of all educational backgrounds believe they are ill-equipped to help. Several national surveys of parents of all income levels have found that they want schools to tell them how to help their children at home, and they want more information about their children's performance in school (16).

Teachers face similar constraints on their time. Many lack training for dealing with parents or have difficulty relating to culturally different families. But studies show that school programs that support parental involvement affect participation more than other factors, including the parent's race, education, family size, or marital status, and even student grade level (13,16,23). Parents whose children's teachers involve them in the learning process report feeling more compelled to help, report that they understand what their child is being taught, and rate the teacher higher in overall teaching ability and interpersonal skills.

When parents are involved with children's learning, teachers maintain higher expectations for students and report stronger, more positive feelings about teaching and their school. They also are less likely to make stereotypical judgments about poor, less-educated, or unmarried parents than other teachers do.

Most importantly, the children of involved parents—especially students from low-income families and ethnic minorities—earn higher grades and test scores (16). Schools also perform better when parents are involved at school. It is estimated that when as few as a third of the parents become actively involved, a school as a whole begins to turn around (16). The performance of all children in the school tends to improve, not just that of the children of those who are more involved. The highest level of student achievement happens when families, schools, and community organizations work together.

The increased presence and connectivity of technology in the home can increase the level of parental involvement by making it easier, more convenient, more interesting, and more productive. Connections with the school can not only accommodate parents' time constraints, but they situate parents' interactions with teachers in the comfortable, familiar context of home experiences and tasks.

In this scenario and the first one, a number of school programs and technological capabilities support parental involvement and communication between the school and the home. Connections between school and home allowed Mr. Zamora to participate in Carmela's experience even though he could not attend. He is also able to help her and her classmates within the constraints of time and place. Finally, he is able to use technology to extend his own learning. Other activities and services facilitated by these connections could be:

BOX D-3: Scenario Three: Connections to Home

Four weeks later, the families of the students and other community members gather to cheer on the student teams as they pit their cars against others in the finals of the National Cyberspace Derby. Steve and his parents walk into the performance center where the other students and neighbors are gathered. Excitement is thick in the air.

"Thank you, everyone, for joining us this afternoon, " Mr. Lindsay, the school-work coordinator, says. "We appreciate Global Car Company's sponsorship of this race and providing the students with our engineering mentor, Ms. Lucero. In the finals, the winner of the race wiIl be the car that is the fastest while getting at least 40 miles per gallon of fuel. All cars have raced in series of regional qualifying runs, and now the best 12 will compete in today's final race. These cars have already rated high on tests of user satisfaction and have come within production budgets. "

On the large projection screen, the audience sees the race from four perspectives. In one window, there is an overhead view of the entire track and the position of each car. Another window displays the track from the driver's seat as students maneuver among their competitors. A third view focuses on the car's instrument panel of gauges showing speed and fuel consumption. Because each car is a computational model, the students can tap into any car on the track, read its gauges, and display them in a fourth window

Lynda, Vincent, Steve, and Carmela huddle around their teleputer as the voice of the announcer comes through the speaker. "Good luck, everybody. Ready, set, GO!"

As the audience cheers, the McAuliffe Cheetahs accelerate their car around the track, moving to the front of the pack

"You're off to a good start, " Ms. Lucero cheers

As the cars lap the cyberspace track, two cars from other communities pull ahead. "Look how much fuel they've used, " yells one parent, pointing to the projection screen. The audience watches the indicator drop quickly as the car in the lead bursts ahead. "See our fuel gauge; we still have plenty left, " Steve shouts.

The community audience groans as the cars reach the finish line. Two cars cross the line ahead of theirs. Then the voice of the announcer says: "While the first two cars that crossed the finish Iine were the fastest, the winner is the car that is both fast and fuel efficient, so our winner is the car that crossed the line third: the McAuliffe Cheetahs!"

Later that night, those from the community who couldn't attend the race live can access a replay of the race on the community's dedicated learning channel. Carmela returns home with her mother to find her father finishing up his latest telecourse lesson. "Congratulations!" he beams. "1 watched the results in the background while I was working on my lesson. Great job!"

Carmela smiles back, "1 knew we could win if we made it more fuel efficient. We checked the fuel efficiency every time we changed the car design. Keeping track of fuel efficiency is really important. We are using it a lot. Ms. Gomez asked us to enter the fuel efficiency of our family cars in the class database for our project on hazardous spills. Can you help me transfer the data from our car's computer?"

Mr. Zamora reaches for the family PDA and calls up the database for their car. The database is automatically updated by wireless communication every time the car pulls into the garage, so the family can keep track of its efficiency and catch problems before they become big ones. "Let's link these data to your classroom database, like this, and it will automatically be updated, too. Let's sit down tomorrow night and go over the data together. We can look at why some cars are more fuel efficient than others "

"Dad, will you mentor this project?" Carmela asks. "The kids want to see how the rail cars are built so they don't spill hazardous waste "

"Sure, let's send electronic mail to your teachers asking how I can help, " he says. "But first, let's replay that winning race!"

- Videotext service and dedicated school video channels that provide continual updates of school activities.
- Electronic mail or voice-mail messages that allow parents and teachers to discuss student progress asynchronously, at times convenient to each.
- Video programs that explain student assignments and provide tips for how parents can participate and help.
- Computer-based assignments, educational projects, and multi-player games that parents can do with their children.
- Extended video-based programs or mini-courses that supplement parents' knowledge of a range of topics from parenting skills to school subjects.
- Switched, interactive video so parents and other community members can tutor children from their homes.
- Community-access video servers that allow parents to share personal photos and audio and video recordings of historical note or personal meaning.

Pedagogical Perspective: Authentic Assessment

Paralleling several other developments described above, there is a national move to change student assessment so that it reflects knowledge as it is used in the world rather than knowledge in the classroom. Authentic assessment moves from the recall of facts and the computation of "answers" to the application of knowledge in situations similar to those in which knowledge will be used in the real world. Correspondingly, judgments are made on authentic processes and products, and the "correctness" of these assessments moves from being the sole responsibility of the teacher to being the shared responsibility of those who participate in and are affected by the application of knowledge.

- Authentic assessment can be supported by technology in many ways, including:
- Designing multimedia assessment tasks that present richly textured scenarios.
- Allowing learners of disparate knowledge, learning styles, challenges/impairments, and language to be equally engaged in the assessment process.
- Archiving the learning process, draft materials, and finished products.
- Recording time spent on tasks and tracking scaffolding.
- Supporting "remote" evaluation of student work.
- Publishing student work and making it available to parents and others in the community.

Pedagogical Perspective: Multiple Representations and Visualization

External representations are the primary means by which people come to understand a phenomenon or concept and express this understanding to others (20). We use words, pictures, sounds, diagrams, numerals, and other symbols to construct these representations and convey meaning to others. Each type of symbol, or symbol system, expresses the meaning of a phenomenon or concept in a different way. A picture of a car racing down a track says something different from the equation $f=ma$, yet both say something about motion, force, acceleration, etc. Making connections across symbol systems or representations is important; in fact, the ability to make these connections is frequently what we mean when we say someone "understands" something. For example, someone understands $f=ma$ when he or she can read a paragraph about speeding cars and use the equation to determine which car will go fastest or need the least force to accelerate.

Technology can be used to support understanding by providing students with one or more symbolic representations of a phenomenon or concept. Students can act on these in some way and observe the results. These multiple coordinated representations can make difficult concepts more accessible to students, and students can build a deeper understanding of the concept by combining the different information provided by each representation (19,20). For example, a student could enter an equation and the technology could provide a graph of the equation. As a consequence, the student has a deeper understanding about both equations and graphs. Or the technology can build on a student's understanding as represented one way to understand the phenomenon as expressed in a different way.

"Stepping on the gas" is a common, everyday experience for students. In the scenario provided, the students can manipulate the graphic object of a racing car so as to "step on the gas" (that is, increase the force), thus increasing its velocity and acceleration. Not only do they see the car speed up (a consequence with which they are very familiar), they also see a numerical representation of its speed and see this numeral change over time. They also see a graph of the relationship between force and acceleration. Thus, they can use their understanding of speeding cars, as represented by pictures, to understand force and acceleration, as represented by numerals and graphs.

Technological Perspective

Networks

During the next 10 years, pressure from four market forces will drive service providers to support broadband (10 Mb/s to 100 Mb/s) and wideband (greater than 100 Mb/s) demands for metropolitan-area networks (MANs) and wide-area networks (WANs):

- Increases in computing power.
- The public's growing appetite for media-rich information.
- Increases in workgroup computing (that is, groupware).
- Performance expectations based on the broadband and wideband capabilities of local-area networks (LANs).

Encircling the McAuliffe community of our scenario is a switched, high-bandwidth, wide-area network composed of fiberoptic cable and high-capacity video servers. The network is extended into homes, schools, automobiles, and offices by an amalgam of fiber, coaxial cables, wireless communication, and a few residual copper wires. Its capacity is increased by a variety of software and hardware compression and decompression utilities. The network is connected to networks around the world via satellite and microwave. Tapped into the network are a range of electronic devices that act and look sometimes like telephones, sometimes like televisions, and sometimes like computers, but they all communicate with each other. Sometimes they are combined into a single information-entertainment "teleputer." This network interconnects the various devices we have described and supports the connections between school, home, and work.

Personal Digital Assistant (PDA)

Learners and teachers will have small, wireless, very powerful information appliances at their disposal and within reach of their budgets in 10 years. Capitalizing on trends in miniaturization, manufacturers are packing more and more computer power into smaller and smaller cases. These developments herald a new class of computing device called a personal digital assistant (PDA). Prices of these devices are dropping rapidly, and, well before 2005, their price points will meet those currently offered by more specialized game platforms such as Nintendo. For example, most analysts anticipate that prices for Apple Computer's Newton PDA will fall to $200 or less by 1996.

Because they carry their PDAs everywhere, learners in our scenarios can work on their projects regardless of their location. In addition to approaching the task in a structured way, students work opportunistically, adding voice annotations, comments and ideas from friends and parents, and pointers to new information that arise during discussions. The major importance of these devices is that they bring computer processing and communications to situations anytime, anywhere. These capabilities will enrich many "informal" (outside the physical school building) learning situations, such as those that occur in the home.

Interactive Digital Video

Cable service providers are scrambling to provide interactive digital video services. As first steps, they are putting in place the infrastructure to provide video-on-demand and interactive home shopping as a replacement for conventional subscriber TV. They are examining both the impact and the requirements of such services in testbeds across the country (27). And, fueled by customer surveys that already underscore the attractiveness of these offerings, companies are building the video servers and set top boxes necessary to support these initiatives. One can already preview modest examples of these capabilities in hotels that offer guests the option to select and watch a movie at a time that matches their schedule or check out through the TV without going to the front desk. The advent of digital video-on-demand, coupled with the development of user-friendly agent technologies, will allow people to search video servers for specific kinds of information and make selections just as people today search and retrieve information from conventional databases.

In this scenario, both the replay of the race and the telecourse that Mr. Zamora is taking are available on large digital video servers. Carmela and her fellow students will also store their multimedia reports on these servers. These and other resources are available to members of the community as they are interested in using them.

Large, Color Display

It is likely that in the next 10 years flat-screen technology will improve sufficiently to accommodate modest display sizes in limited locations. The federal government has made a financial commitment to keep the United States competitive in this technological arena. For example, Xerox Corporation has recently received significant amounts of government funding to develop flat-panel technology for the U.S. military. We expect that in 10 years, following this developmental phase, the prices of large (4-ft x 3-ft) flat panel displays will reach price points equivalent to today's high-end consumer televisions ($2,000-$3,000).

In this scenario, the community has access to this still-expensive technology through the multimedia performance auditorium at the McAuliffe Learning Center. This display serves the important purpose of providing a common experience to a large group of people. The community members can participate in the achievements of their children and share in the satisfaction of their accomplishments.

IMPLICATIONS

Reiterating the point that began this paper, the vision that we present has significant implications for social change that go beyond the development of advanced technologies. Some of these implications we have embedded in our scenarios and their analysis. Others are more pervasive and represent the larger social context beyond school, home, and business connections and relationships. Making the vision that we present a reality will depend on changes in the way teachers teach and use technology, on the way education is supported and schools are held accountable, and on the universal availability of the services we describe.

■ Teachers and Teacher Training

Sheingold (34) concludes that the human side of technology introduction is a much bigger barrier than lack of technology per se. To fulfill our vision, teachers would need to learn not only to use the various technologies described in our scenarios, but also to design, structure, guide, and assess progress in learning centered around student projects.

This kind of teaching, which most teachers have rarely experienced in their own education, requires wide-ranging subject matter expertise, creativity, and intellectual confidence. Teachers need to help students design projects that will incorporate important content and be able to provide key ideas or strategies for helping students overcome impasses encountered in their work. Teachers need to be comfortable letting their students move into domains of knowledge where the teachers themselves lack expertise; teachers need to have the intellectual confidence to be willing to model their own reasoning process when they encounter phenomena they do not understand or questions they cannot answer. Teachers need to be creative in finding ways to embed measures of student understanding within group projects, no easy task when multiple groups are working concurrently and different students assume different roles within their groups. Teachers must be able to roam from group to group physically and electronically, providing stimulation and coaching without dominating the group process.

This new role for teachers is challenging and requires a very different kind of teacher education program, one in which prospective teachers are taught in the way we wish them to teach, and technology use is integrated into all preservice education classes rather than treated as the topic for a single, isolated class. Today's teachers need a great deal of professional support for learning to teach in new ways and to incorporate technology into these practices. They do not need the one- or two-hour workshop that is so prevalent today. They need regular blocks of time built into their work schedules in which they can plan project-based, technology-supported activities and assessment methods, as well as opportunities to observe classrooms where such work is going on. They need a chance to interact with a professional group of colleagues interested in the same kinds of instructional approaches and subject matter to get feedback on their new approaches, pointers to useful information, and encouragement for getting over the inevitable setbacks. Technology can help develop such groups through electronic networks and through "video clubs," in which teachers share and discuss videotaped excerpts from their classrooms. However, administrators and policy-makers need to provide the resources to support time for teachers to engage in these activities and develop expertise in their new roles.

If learning and teaching change in the ways we envision in these scenarios, the profession of teaching will change drastically. Teachers will assume a more executive role, setting goals and providing guidance, support, and evaluation, but letting the students carry out most of the learning activities. This new role entails curriculum development (as they work with students to design projects), team building, diagnosis of individual learning needs, assessment of individual student progress, and exploration of questions in a broader, unspecified range of content domains. Just as business professionals employ a variety of technology tools to increase their access to information and ability to make sense out of it, teachers will need a range of technology supports for designing learning materials, performing assessments, keeping track of curricular goals and achievements, and communicating with other teachers, information resources, students, and parents. No longer will teaching be the single profession in which practitioners cannot expect ready access to a telephone. Teachers will need to have technology tools available to them for their own as well as their students' use.

The teachers we describe, with well-developed skills as technology users and greater interaction with the worlds of research and commerce, are likely to find an increase in their status and in the number of nonteaching opportunities available to them. Side effects of this change in role could well include pressure to increase teacher salaries and a greater diversity among those who choose the profession.

Accountability and Public Support

From a public policy perspective, accountability concerns are a driving force in federal, state, and local education spending. Federal and state education agencies are offering local jurisdictions more flexibility in their education programs in exchange for accountability with respect to curriculum standards. Some might infer quite different visions of technology use from those described here, based on trends stressing curriculum standards and assessment of student performance relative to those standards. One could extrapolate from the national Goals 2000 legislation to the use of technology as the transmission mechanism for "approved" instructional content tied to curriculum standards and as a tool for collecting student assessments (for example, through computerized adaptive testing, which permits the coverage of more content with fewer test items per student). Many software publishers are looking forward to the development and voluntary adoption of national curriculum standards because they have the potential to create broader markets for instructional software tied to a single national curriculum, rather than the patchwork of state and local curricula that makes software design difficult and fragments the market.

We offer a very different vision of technology use, one in which the same kinds of technology tools used in work settings and homes are available to students and teachers, and are incorporated into challenging learning activities where students design projects around their own interests with guidance and support from their teachers and outside mentors. We have not ignored these policy concerns, however. We suggest that sophisticated software tools can be developed to support teachers in injecting important curriculum content into student projects and in keeping track of student achievement of instructional goals. This technological aid is quite feasible, provided that teachers have the training and time for its use.

What is perhaps less clear is public acceptance of this approach to learning and of a system of assessing students in the context of authentic group projects. As Cohen (8) points out, the majority of the public adheres to a very conventional model of education as knowledge transmission and assessment as performance on standardized multiple-choice tests. In many cases, departures from conventional content, teaching practices, or assessment are seen as attempts to avoid high standards. Parents want to know where their children stand in relation to other children and where the student body of their school stands in relation to those of other schools on traditional academic subject matter.

Our scenario for the future requires a real change in this perception. It will come about only if there is increased dialogue between educators and the community they serve, as well as strong evidence that project-based learning activities support the attainment of higher skill levels and that authentic assessments provide information that is at once educationally useful *and* predictive of how well students will perform future tasks of interest, whether college performance or ability to function effectively on the job. Given the difficulty of making widespread, fundamental changes in teaching practices, a strong body of research and evaluation evidence supporting these practices must be generated and disseminated to policymakers and the public if the kinds of practices we describe are to be commonplace in the year 2005.

Equity and Access

The biggest assumption in our scenarios is that students and their families will have near-universal access to high-end technologies. As technology connects learning environments and homes, it becomes increasingly important that differences in socioeconomic status not create an electronic form of school segregation between the technological haves and have-nots. Government and school programs and regulations will need to assure the accessibility and affordability of at least a minimum form of network service for all homes.

Although the growth in the number of computers and video-based technologies in schools has been exponential (2), the number of hours per week that individual students have access to technology is still very low in most schools. Moreover, those schools serving children from economically disadvantaged homes have less access to technology than do those serving more affluent communities (3) and, when they do have access to computers, are less likely to use them in ways other than drill-and-practice (12). In some states, school budgets are stretched so tightly that students must share basic texts; under such circumstances, teachers have a hard time building enthusiasm for learning to use new technologies.

There are positive signs, however, that the issue of equity is getting more attention. School financing mechanisms that leave areas with low property values with very limited per pupil educational funding are being challenged successfully in many states. At the same time, federal compensatory education programs are focusing more on schools serving the largest proportions of poor children. Federal guidelines are encouraging schoolwide programs and supporting the acquisition of technology and implementation of parent involvement programs as part of the effort to improve the educational prospects for children at risk of school failure.

Corporate support for education programs, particularly programs that incorporate technology, is at an all-time high and is likely to continue. The business community has become much more aware of its dependence on a well-educated workforce and of the changing cultural, gender, and ethnic composition of that workforce. Many corporations are making a particular effort to reach out to schools serving large numbers of children from less affluent homes, where computer technology is usually absent.

Current trends are not sufficient to reach our vision, however. Stronger efforts are needed on the part of federal, state, and district education agencies to make sure that schools serving larger concentrations of students from poor homes have not only equal access to equipment, but also equity in terms of the quality of technology-supported learning activities.

The concentration of government resources for technology in schools serving larger proportions of children from low-income homes will not bring real equal opportunity, of course, if the students do not have the same kinds of home resources used by other students and their caregivers. Our scenarios assume that a rich array of broadband services will be as commonplace and low in cost as television or the telephone. Without something approaching universal access and perhaps special rates for low-income households, we will not see the kind of across-the-board parental participation described here.

Another way to make technology accessible to parents is to make school equipment and services available during nonschool hours. Part of the scenario takes place in a technologically and socially rich community center located in the school. The coordination and co-location of community groups, social services, and educational programs can increase the impact of these services and increase their efficiency. Making these resources available to parents and students during nonschool hours can further increase impact and reinforce educational goals. As a place where parents and children come together to engage in learning activities, the learning environment can become the center for building communities of understanding.

CONCLUSION

The technological developments that we have discussed will be driven to a large extent by the business and consumer markets and funded by private capital. There is an important role, however, for government leadership, regulation, and support.

Central to our vision of communities of understanding, of course, is the community. Community leaders will play a pivotal role in making education the focus of community life and in nourishing the values that support education.

State and federal governments also can facilitate the development of communities of understanding in the policies and regulations that they make related to the emerging National Information Infrastructure (NII). Current models of the NII envision schools connected to each other and to libraries and museums. This level of interconnection is insufficient to realize our vision; schools must also be connected to homes and workplaces. As state and federal agencies review regulatory policies, they should require telephone companies and cable companies to provide phased-in universal service as they install advanced technologies, much as telephone companies are currently required to provide universal voice services. At the same time, policies should be structured so that service providers are responsive to community needs, much as current structures require cable companies to negotiate with local communities around the terms of their franchise. Policies and funding should encourage and support the experiments of local communities to interconnect schools, homes, and workplaces to support education.

In forming policies, it is vitally important that differences in socioeconomic status not result in an electronic form of segregation between the technological haves and have-nots. Policies will be needed to assure accessibility and affordability of at least a minimum form of network service for all homes, schools, and communities. Furthermore, it is important that this minimum service be interactive. An NII that allows some to both create and receive information while others are able only to receive it would institutionalize radical inequities and disenfranchise segments of society. Equity and access must be paramount considerations.

Finally, state and federal agencies dealing with education, labor, commerce, and science and technology should act in a coordinated fashion to encourage collaboration between the public and private sectors and to foster the development of tools, materials, services, and resources that support educational reform and make the NII pay off for students and schools.

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Appendix E Public School Teachers Using Machines in the Next Decade

E

It is hard to be clever about the folly of making predictions. I could cite instances of those who have predicted everything from the end of the world to the end of printed books. I could cite others whose business is forecasting the immediate future as, for example, Central Intelligence Agency executives who missed the collapse of the Soviet Union. Or I could turn to those who saw a revolution in schoolteaching with the invention of film, radio, television, and computers. None of these is clever or even amusing.[1]

I prefer candor to cleverness so, with the risks of forecasting in mind, I will create three plausible "futures" of teachers using computers, CD-ROMs, modems, and other telecommunications in their classrooms. These scenarios will have a patina of credibility because they are anchored in what exists now and are seasoned with the experiences of both partisans and opponents of teachers using these machines in their classrooms. I then will identify the most likely of these three scenarios to occur in teachers' classrooms. I am reasonably confident which scenario will materialize, although the less courageous side of me surrounds the likely "future" with at least one qualifier.

So, I want to be clear at the very beginning of this essay that my "prediction" is no more than an educated guess based upon the claim that schools are unique organizations, the fabric of social

by

Larry Cuban

Stanford University

[1] For recent prophesies about the end of printed books, see D.T. Max, "The End of the Book?," Atlantic, vol. 274(3) September 1994, pp. 61-71. For forecasts on electronic machines' impact on public schools, see Larry Cuban, *Teachers and Machines: The Use of Classroom Technology Since 1920* (New York, NY: Teachers College Press, 1986).

beliefs woven around public schools, and what has occurred in the past when practitioners faced electronic machines.

In this paper I will argue that the spread of telecommunications in businesses, industries, the military, and other organizations make comparisons to getting teachers to use computers in their classrooms facile but misguided because the classroom as a workplace, the nature of teaching groups of children, and public expectations for schools differ substantially from other institutions.

Such casual comparisons, I will argue, are driven more by a mind-set that frames the problem of snail-like progress in getting teachers to use the technology as an engineering problem. That is, the organization is basically in good order; what it needs is a heavy dose of efficient managing and quality control. If teachers are not using the damn machines, get more of them, train the teachers to use them, provide continuous hardware maintenance and technical assistance to teachers and, by God, there will be more students on those machines. Framing the problem this way is popular and dominates the thinking of many advocates for telecommunications in schools.

A less popular way of framing the problem is seeing the very slow (and, as partisans would say, unimaginative) use as a problem of poor design and stubborn traditional beliefs. That is, the present school structures (e.g., age-graded schools) and cultures (e.g., norms of teacher self-reliance rather than collaboration) that dominate the teacher's workplace need to be redesigned with teaching and learning kept foremost in mind for innovative technologies to be used in classrooms routinely. Second, the redesign will have to take into consideration dominant popular beliefs about what teaching is, how learning occurs, what knowledge is proper in schools, and the teacher-student relationship. These traditional beliefs inform mainstream views of a proper schooling. It is, however, the engineering approach, not the redesign approach, to getting teachers to use telecommunications that currently dominates the popular and research literature on teacher use of technologies.[2]

There are very good reasons why the problem of limited teacher use of technology is framed less often in design terms. Previous school reforms that swept across the nation largely ignored technology. Moreover, the entangled impulses that drive reformers to press teachers to use new technologies seemingly mirror those very same impulses in manufacturing, banking, medical science, the armed forces, and other organizations that have automated many of their essential operations. Engineered solutions worked there. Why not in schools?

I then turn to three scenarios that I constructed as credible alternative futures and assess which one is likely to occur. To make this entire argument concrete and coherent I will concentrate on teacher use of computers.

THE SPREAD OF COMPUTERS IN SCHOOLS: CONFUSION OVER ACCESS, USE, AND INNOVATION

School use of computers has spread swiftly, widely, and, on occasion, deeply. In 1981, for example, there were, on average, 125 students per computer; in 1991, there were 18. As new schools are built that are wired for information technologies

[2] See, for example, U.S. Congress, Office of Technology Assessment, *Power On!: New Tools for Teaching and Learning*, OTA-SET-379 (Washington, DC: U.S. Government Printing Office, 1988); Office of Technology Assessment, "Project Proposal: Teachers and Technology," 1993, pp. 1-12.

and the ratio of machines to students drop to 4:1 or even less, hopes escalate for wider and more sophisticated uses of the machines.[3]

A closer inspection of those and other figures commonly used to display the swift penetration of the technology into schools, however, reveals the frequent confusion between access and use. For those individual students who use computers (and not all do) they spend, on average, a little more than one hour a week (or 4 percent of all instructional time). Moreover, what students do with computers varies greatly. For 11th grade students who use the machines, to offer another example, computers were seldom used in subject areas; where they were used, the purpose was to teach about computers. An Office of Technology Assessment (OTA) study concluded that students from high-income families have far more access to computers in schools than peers from low-income families. Black students use computers in schools less than white, especially in elementary schools. Pupils whose native language is not English have even less access to computers. Finally, low-achieving students are less likely to use machines to enhance reasoning and problem solving and more likely to use them for drill and practice.[4] What appears as a rampaging innovation threatening to reform the conduct of teaching and learning, then, is much less than meets the eye. And that has been the case with earlier technologies groomed as tools for reforming traditional classrooms.

TECHNOLOGIES AND SCHOOL REFORM

What is curious about current information technologies and their earlier incarnations is that none were associated with national reform movements. If there is any pattern at all in the movements to reform schools that have swept across the nation since the middle of the 19th century, none were dependent upon instructional technologies beyond a teacher, blackboard, textbook, and pen and paper.

Mid-nineteenth century common school leaders Horace Mann, Henry Barnard, and others sought to make schooling accessible to all students regardless of ethnicity or class. They created thousands of schools where students could attend, prepared teachers for those schools, and installed a common curriculum accessible to those who attended. Although instructional technologies were absent from such a movement, a managerial technology—a systems perspective—was present in the organizing of age-graded elementary schools

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[3] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of The United States, 1991* (Washington, DC: U.S. Government Printing Office, 1991), p. 150; Quality Education Data, "Technology in Public Schools, 1991-1992: Extract (Denver, CO: Quality Education Data, 1992), pp. 1-2. For examples of new schools there is the $19.6-million Quince Orchard High School in Montgomery County (Maryland) where there are 288 computers for 1,100 students. Or the Juan Linn School in Victoria (Texas) where a computerized Integrated Learning System (ILS) provides instruction to 500 students and records daily their work. See "Computers in School: A Loser? Or A Lost Opportunity," Business Week, July 17, 1989, p. 108.

[4] *Power On!*, op. cit., footnote 2, p. 6. These figures, however, obscure the imaginative applications of computer technology to instruction in special education where blind, deaf, and multiply-disabled students are able to read, write, and communicate in ways that heretofore were unavailable and of new software for drafting courses, auto mechanics, business, and other vocational courses. See The Alliance for Technology Access, a network of resource centers that specializes in using computers to help individuals with disabilities. They publish an occasional newsletter, *CompuCID*, the Computer Classroom Integration Project; also see Susan Russell, Rebecca Corwin, Janice Mokros, and Peggy Kapisovsky, Beyond Drill and Practice: Expanding the Computer Mainstream (Reston, VA.: The Council for Exceptional Children, 1989).

Such figures also ignore the massive computerization of administrative work in districts and schools previously done by typewriters and telephone. Computerized data processing, for example, has converted the making of district bus schedules, high school course selections, payroll operations and the reporting of grades into routine activities that take a fraction of the time formerly used for these tasks. Increasingly, teachers use software to prepare lessons, notes to students and parents, classroom newsletters, attendance and grade-report records. In libraries, card catalogues are electronically available. The overall picture after the introduction of the personal computer a decade ago and persistent efforts to improve schooling suggest, at best, that computers are an expanding but marginal activity in schools with wide variation in administrative, teacher, and student use.

and subject-centered, departmentally-focused high schools with their multi-period daily schedule of recitations.[5]

A half-century later, another generation of reformers sought to transform schools into instruments of social reform. These progressive education reformers wanted schools to turn millions of immigrants into Americans and reduce the corrosive effects of slum housing, urban crime, and poverty. Moreover, reformers wanted these schools to focus on more than the child's mind; their psychological and social development were part of the educator's responsibility. Furthermore, what children studied had to change because they learned best when their interests were harnessed to what occurred in the home, community, and nation. Throughout the early 20th century, progressive educators sought ways of transforming schools to secure these aims. Many educators in pre-World War II schools saw the invention of the motion picture and radio as useful tools to help achieve their aims. But these new technologies were marginal to their vision for new forms of teaching and learning.[6]

Since World War II, a series of national reform movements to improve schools included raising academic standards in the 1950s, desegregating schools and creating open classrooms in the 1960s, and instituting back-to-basics and minimal competency testing in the 1970s. New instructional technologies were mentioned and even promoted temporarily (such as television and programmed learning in the 1950s and 1960s and computer-assisted instruction in the 1960s and 1970s), but the center of gravity to any of these national reforms was nontechnological. Machines were mere blips on the outer edges of reformers' radar screens.[7]

This has not been the case in the 1980s and 1990s. With massive technological changes in the workplace and daily life, school reformers throughout the last decade increasingly have turned to putting computers in schools as a high-tech, engineered solution for ineffective, even primitive, teaching by textbooks. Hundreds of formal reports from corporate leaders, foundations, professional associations, and federal agencies consistently have underscored how schools have failed in achieving their academic purposes and how, in that failing, have contributed to the nation's economic decline.[8]

Thus, in the 1980s and early 1990s, strong impulses to introduce higher quality control into public schools moved these coalitions of reformers that included corporate executives, public officials, foundation officers, school administrators, and teachers to embrace computers and telecommunications as a way of unfreezing the perceived inefficiencies and rigidities of American schooling.

IMPULSES FOR USING LATEST TECHNOLOGIES IN SCHOOLS

Basically, three impulses converged in reforming schools through electronic technologies. Al-

[5] For the common school movement, see David Tyack and Elisabeth Hansot, *Managers of Virtue* (New York, NY: Basic Books, 1982); Carl Kaestle, Pillars of the Republic (New York, NY: Hill and Wang, 1983).

[6] For general history of progressive movement in education, see Lawrence Cremin, The Transformation of the School (New York, NY: Vintage, 1961); for the penetration of these ideas into schools and classrooms, see Larry Cuban, *How Teachers Taught,* 2d edition, (New York, NY: Teachers College Press, 1993) and Arthur Zilversmit, *Changing Schools: Progressive Education Theory and Practice* (Chicago, IL: University of Chicago Press, 1993).

[7] For post-World War reforms, see Diane Ravitch, *The Troubled Crusade* (New York, NY: Basic Books, 1983).

[8] T*he Nation at Risk* (1983) report, for example, forged the linkage between economic decline as a nation and decline in standardized achievement test scores. The report recommended a half-year of computer science as a high school graduation requirement. See National Commission on Excellence in Education, *A Nation at Risk* (Washington, DC: U.S. Government Printing Office, 1983), p. 26. Also see, for example, David Hornbeck, "Technology and Students at Risk of School Failure" in Arthur Sheekey (Ed.) *Education Policy and Telecommunication Technologies* (Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement, 1991), pp. 1-2.

though I offer them separately, they are entangled and technological enthusiasts often combine one or more of these impulses in their advocacy for a particular technology.

First, there is the drive to bring schools technologically in step with the workplace because of the fear that students will be unprepared both to compete in the job market and adjust to the changing marketplace where bank teller machines, bar codes on products, answering machines, and other electronic devices prevail. The computerized workplace and the ubiquity of telecommunications in daily routines outside the home have convinced advocates of modernizing schools that students must become familiar with electronic technologies. Computers, in other words, are the future and schools must prepare students for it.[9]

A second impulse has come from a diverse coalition of academics, educators, and foundation officials who have neoprogressive values of children engaged in self-directed learning. This coalition, leaning upon the work of American (John Dewey and Jerome Bruner), European (Maria Montessori), and Russian (Lev Vygotsky) scientists and educators, seeks to overhaul classrooms where learning is tediously absorbing knowledge largely unconnected to daily life. They want schools where teachers help students construct their own understanding. Neoprogressives view students as active learners creating knowledge that makes sense to them. They want schools where such knowledge is shared by all members of the community; schools where diverse mixes of adults and children work easily together in varied groupings. Hence, interactive computers and telecommunications are mind-tools that help students grasp concepts, use all of their senses, and practice what they have learned creating self-directed learning communities, according to such advocates.[10]

Finally, there is the impulse for productivity. This highly prized value of making teaching and learning efficient is historic and, when harnessed to electronic technologies, unrelenting. The lure of productivity—teaching more in less time for less cost—can be traced back to the origins of public schools in the early 19th century and has been a consistent goal for schooling ever since.[11]

Advertisements for computers make similar points today without hesitation or subtlety. IBM has run an ad for the last few years that has a clever set of photos showing the same teacher working with different students in her class simultaneously. The caption reads: "With IBM, there's a practical way for teachers to be everywhere at once." The ad copy says:

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[9] In examining the impulses driving recent reform coalitions, I read the reasons reformers used in explaining why new technologies were crucial in improving schools. I merged reasons that I felt were close enough to be cousins and, in doing so, probably created both ambiguity and mild confusion, if not annoyance, for some readers who wanted clarity. For a more exact delineation of the specific impulses for computers in schools, see Israel Scheffler, "Computers at School?," *Teachers College Record*, 87(4), Summer 1986, pp. 514-528.

[10] I use the word "neoprogressive" to link the ideas of these reformers with those of a century earlier who were pedagogical progressives challenging the then-inflexible ways of teaching, learning, and organizing schools. The ideas of Francis Parker, John Dewey, William H. Kilpatrick, and such diverse practitioners as William Wirt and Ella Flagg Young were applied to schools and classrooms in the decades before and after the turn of the century. Notions of active engagement of children in what they were learning, group work on projects, and focus on both the mind and emotions of children as they developed were central to this earlier generation of reformers. See Lawrence Cremin, *The Transformation of the School* (New York, NY: Vintage, 1961); David Tyack, The One Best System (Cambridge, MA.: Harvard University Press, 1974).

For instances of these ideas in print, see Howard Gardner, *The Unschooled Mind: How Children Think and How Schools Should Teach* (New York, NY: Basic Books, 1991; John Seely Brown, Allan Collins, Paul Duguid, "Situated Cognition and the Culture of Learning," *Educational Researcher* (Jan.-Feb., 1989), pp. 32-41. For a clear portrayal of the neoprogressive view insofar as using computers, see articles by Judah Schwartz, Sylvia Weir, and the writers for the Laboratory of Comparative Human Cognition in "Visions for the use of Computers in Classroom Instruction (February 1989) and "Responses to 'Visions for the Use of Computers in Classroom Instruction'" (May 1989) in *Harvard Educational Review*, 59(3), pp. 206-225.

[11] See, for example, Carl Kaestle, (Ed.) *Joseph Lancaster and the Monitorial School Movement* (New York, NY: Teachers College Press, 1973); Raymond Callahan, Education and the Cult of Efficiency (Chicago, IL: University of Chicago Press, 1962) Arthur Melmed, "Productivity and Technology in Education," *Educational Leadership*, February 1983, pp. 4-6; *Power On!*, op. cit., footnote 2, pp. 171-172.

> With an IBM network, teachers are discovering how to do the impossible: deliver quality, individual instruction to every student. It is possible because students are working with a tool that is infinitely patient . . . teachers are free to evaluate student progress and help when a need arises. [12]

"Faster, better, and cheaper" is the drumbeat of the productivity impulse.

These interlocking impulses have fueled the surge in school purchases of information technologies in the 1980s and early 1990s. But as the figures cited earlier revealed, teachers' use of computers and telecommunications have yielded mixed results.

Some obvious questions arise. Is the growing number of new schools devoted to using computers and telecommunications a sign that these are, indeed, schools of the future? Or is the apparently marginal use of computers in classrooms a sign that this technology is going to be used just like earlier ones, that is, peripherally, seldom disturbing customary ways of teaching and learning? Or is this marginal use of computers in schools a sign of steadily growing acceptance of the new technologies and that, within time, most classrooms will become more machine-friendly?

These questions ask about the future so I will sketch out three scenarios of what might be 10 years from now. Each storyline is plausible and has substantial evidence to support it. After describing each I will pick one that I believe is likely to be dominant a decade from now.

THREE SCENARIOS

The Technophile's Scenario: Electronic Schools of the Future, Now

A decade from now schools will have enough machines, software, accessories, and wiring to accommodate varied groups of students in classrooms, seminar rooms, and individual workspace. The technophile's vision driving such schools is anchored in making teaching and learning far more productive and meaningful than both are now. [13]

Better machines and software are central to this vision; they are seen as tools for both teachers and students to liberate themselves from inflexible ways of teaching and learning. Students will come to rely on the machines and one another to teach each other; teachers will become coaches to help students with what needs to be learned. Frequent lectures, recitation, textbook assignments, and 50-minute periods will be as implausible as dinosaurs in a zoo.

The strategy for achieving the vision is to create total settings that have a critical mass of machines, software, and like-minded people who are serious users of the technologies. Technophiles believe in making big changes swiftly rather than creating pilot programs in schools or incrementally buying a few machines at a time.

Two examples of the technophile's vision inspired by mixes of the three impulses described earlier may help make the scenario vivid. Consider first a productivity-driven version of the scenario that emphasizes, in a phrase favored by advocates, "instructional delivery systems."

> A student would take his paper to a writing center where he would be asked by a terminal to type his name, his teacher's name, and the title of his paper. Having done this, the computer screen will then ask him to input the first symbol that the faculty member has written on his paper. Here the student might type CS or rule #42, and the screen would say, 'John, this is the third time you have missed a comma splice. In your papers entitled 'My Most Embarrassing Moment' and 'An Analysis of Two Poems by Emily Dickin-

[12] *The School Administrator*, May 1989, between pages 15 and 18.

[13] What I call "technophiles" Thomas P. Hughes calls "technological enthusiasts." His study of American inventions and growth of systems for using technology (electrical industries, manufacturing, etc.) between 1870 and 1970 makes clear that the present moment of vibrant hope for the future that technophiles aspire to is part of a larger enthusiasm that is typically American. See Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm* (New York, NY: Viking, 1989).

son' you had comma splices, and you have not yet mastered what a comma splice is. I am going to explain it to you once again, give you some drill and practice until you have mastered it, and urge you not to make this mistake again. . . .'

At the end of each instructional period in the computer center, a list will be given to the teacher which divides the students into various groupings of approximate ability as of that day. Thus the teacher will be able to work individually with groups that are quite close together back in the classroom. The [computer lab] managers will also generate individual seatwork on a high-speed printer that the students can take back to their rooms with them. Thus, while some may be working with teachers in individual groups, others might be doing individualized seatwork with problems generated to their precise level at that moment. . . .[14]

Other technophiles offer neoprogressive flights into the future to dramatize how new technologies can create student-centered schools. One example will give a distinct flavor for this version of the scenario. In this instance, a high school senior from a fully computerized school is applying for a job at a TV station.

She looked through her portfolio for the hundredth time. She hoped she had everything that she needed and that the battery on her notebook computer held up. She had her early work from the other clusters too. She had even brought her ID disk, in case Mr. Martin wanted her to see the hologram that showed the paths she chosen to reach Mastery [in the curriculum].

'Come on in, Laura. . . .' Laura sat nervously on the edge of the chair next to Mr. Martin. "Well, Laura, how are you? Are you ready to show me what you've accomplished?'

'Yes, sir, I sure am!' Laura relaxed as she began to talk about her projects. . . . 'I'm interested in long-range weather planning and its implications on international relations. . . .' Laura handed Mr. Martin her disk as he activated the laser wall display. As the images of her data began to appear, she described in detail the steps she had taken in the completion of her prediction simulation. . . .

'Well, Laura, you've done a good job. Tell me about some of your other activities in school.'

'I did my first rotation when I was eight. It was at the Materials and Manufacturing Cluster. We compared the differences between bread baked in a bakery and bread baked at home. Boy, did we eat a lot of bread!' Laura showed Mr. Martin the IBM floppy disk that she had kept all these years. . . .

Laura left the interview with a good feeling. . . . She knew he appreciated her computer skills. She just hoped he looked at the hologram so he could see all the other things she had done.[15]

The Preservationist's Scenario: Maintaining While Improving Schooling

In this scenario, policymakers and administrators put computers and telecommunication technologies into schools largely to improve productivity but not to alter substantially existing ways of organizing a school for instruction. While some teachers and administrators use these technologies imaginatively and end up being profiled by the media, most uses are fitted by teachers to the durable grammar of the classroom and school.

The vision buried within the preservationist's story is one of schools continuing to do for society

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[14] Dustin Heuston, "The Future of Education: A Time of Hope and New Delivery Systems," unpublished paper, WICAT systems, Orem, UT, 1986, cited in Royal Van Horn, "Educational Power Tools: New Instructional Delivery Systems" Phi Delta *Kappan*, March 1991, pp. 527-533, quote is on p. 533.

[15] Draft of *Texas Technology Model for 2061 Project,* 1991, pp. 2-4; For another example of older students using technologies in an early 21st century "school," see Christopher Dede, "Imaging Technology's Role in Restructuring for Learning," in Karen Sheingold and Marc Tucker (eds.) *Restructuring for Learning and Technology* (New York, NY: Center for Technology and Education, Bank Street College of Education, 1990), pp. 51-52.

what they have historically done: pass on prevailing values, and accumulated knowledge to the next generation, improve ways of teaching and learning the prescribed curriculum, sort out those children who achieve academically from those who do not, and give taxpayers as efficient a schooling that can be bought with available funds. Skepticism towards major changes, hammered out of these traditional aims for schooling, leads to adding-on to what exists now.[16]

Much evidence makes this scenario plausible. Some examples: mandating computer literacy as another graduation requirement; adding computer science courses to the curriculum; creating computer labs where teachers bring their classes; placing one computer in each classroom; buying software that is part of a textbook adoption; finally, a school buying an integrated learning systems (ILS) that centralizes daily math and reading lessons for each student with results of the students' work being reported the next day. [17]

In this scenario, computers and other forms of technology are seen as important but peripheral to the main business of teaching students. The result is that new technologies reinforce what schools have done for over a century.

The Cautious Optimist's Scenario: Slow Growth of Hybrid Schools and Classrooms

In this scenario, cautious optimists believe that putting computers into classrooms will yield a steady but very slow movement towards fundamental changes in teaching and schooling. Advocates of this scenario see it occurring slowly but inexorably, much like a turtle crawling towards its pond. It is slow because schools, as organizations, take time for their teachers to learn how to use computers to guide student learning. It is inexorable because, as Allan Collins says, "[T]he nature of education must inevitably adapt to the nature of work in society." [18]

Here again appears reformers' productivity-driven dream of efficient machines freeing students from the tedium of traditional teaching—but in this scenario enthusiasts for faster, better, and cheaper instruction and learning need to be ultra-patient. A competing neoprogressive picture of the future also rests within this story: schools can become small learning communities where students and adults teach one another through a deliberate but slow application of technologies to schooling.

There is some evidence for this scenario. Introducing a half-dozen computers into a classroom or creating micro-computer labs, over time, alters how teachers teach (e.g., they move from teaching the entire class as one group to using small groups and for example, David K. Cohen, "Educational Technology and School Organization," in Raymond Nickerson and Philip Zodhiates (eds.) *Technology in Education: Looking Toward 2020* (Hillsdale, NJ: Lawrence Erlbaum Associates, 1990), pp. 231-264. Cohen examines

[16] The essays of David K. Cohen describe well this scenario. He has analyzed elegantly why electonic technologies are marginal to the conduct of schooling. See, for example, David K. Cohen, "Educational Technology and School Organization," in Raymond Nickerson and Philip Zodhiates (Eds.) Technology in Education: Looking Toward 2020 (Hillsdale, NJ: Lawrence Erlbaum Assosiates, 1990), pp. 231-264. Cohen examines the fit between innovative technolieges—in general—and the scarcity of incentives for changes within public education. HIs emphasis on the social organization of the school mirrors my own and has enriched my anlaysis. Also see David Tyack and Elisbaeth Hansot, "Futures That Never happened: Technology and the Classroom, " *Education Week*, Sept 4, 1985, p. 40. My first foray in this subject, *Teachers and Machines*, offered an argument and evidence for this scenario also. Brian Winston makes the preservationist's point by his "law of suppression of redical potential." A new technology that can substantially alter organizational routines and practices, he argues, is viewed by members of an organization as a way of accomplishing more easily and efficiently what thay are already doing. See *Misunderstanding Media* (Cambridge, MA: Harvard University Press, 1986).

[17] *Power On!*, op. cit., footnote 2, pp. 201-202.

[18] Allan Collins, "The Role of Computer Technology in Restructuring Schools" in Sheingold and Tucker, *Restructuring for Learning with Technology*, op. cit., footnote 15, p. 36.

the fit between innovative technologies—in general—and the scarcity of incentives for change within public education. His emphasis on the social organization of the school mirrors my own and has enriched my analysis. Also see David Tyack and Elisabeth Hansot, "Futures That Never happened: Technology and the Classroom," *Education Week*, Sept. 4, 1985, p. 40. My first foray in this subject, Teachers and Machines, offered an argument and evidence for this scenario also. Brian Winston makes the preservationist's point by his "law of suppression of radical potential." A individualized options) and how students learn (e.g., they come to rely upon one another and themselves to understand ideas and to practice skills). In schools where the numbers of computer-using teachers and hardware reach a critical threshold, different organizational decisions get made. Teachers from different departments or grades begin to work together and move towards changing the regular time-schedule. Schoolwide decisions on using technologies become routine, as do decisions on nontechnological matters. Hybrids of the old and the new, of teacher-centered and student-centered instruction, proliferate in this scenario. [19]

Hybrids also can be found in individual teachers working alone in their classrooms. Teachers report how they wove computers into their regular work with students:

Telecommunications has helped students in my French classes use the language they are learning in a meaningful context. We have written collaborative stories with students in other schools, exchanged ideas on pollution and the French Revolution with students in France, participated in an international conference based in Paris, and consulted French travel databases in the French MINITEL. . . .[20]

Now, which of these scenarios is likely to occur, that is, has a 75 percent chance of happening in most schools across the country?[21]

WHICH IS THE LEAST LIKELY SCENARIO?

The least likely scenario is the electronic school of the future. While such schools will be built, they

[19] Denis Newman, "Technology's Role in Restructuring for Collaborative Learning," (Paper presented to the NATO Advanced Research Workshop on Computer Supported Collaborative Learning, Maratea, Italy, September 1989. David Dwyer's work at Apple Computers in researching and evaluating Apple Classrooms of Tomorrow (ACOT) has yielded a number of studies, in particular, schools that support this neoprogressive vision of teaching, learning, and slow change in organizing of instruction. See Jane David, "Partnerships for Change," ACOT Report #12, Apple Computer, Inc., Cupertino, CA, 1992; Robert Tierney, Ronald Kieffer, Laurie Stowell, Laura Desai, Kathleen Whalin, and Antonia Moss, "Computer Acquisition: A Longitudinal Study of the Influence of High Computer Access on Students' Thinking, Learning, and Interactions," ACOT Report #16, Apple Computers, Inc., Cupertino, CA, 1992.

A hybrid of neoprogressive and behavioristic influences can be seen in recent generations of ILSs. One of the most sophisticated that I have seen (as of 1992) is RAMA 3, a multi-subject computer-assisted instructional program for grades 1-8 created at the Center of Educational Technology in Tel Aviv, Israel. Earlier versions of the ILS are being used by over 100,000 students, or almost 10 percent of the total school population. The system not only includes powerful computers and software programs but printed booklets, continuous staff development for teachers, and a large maintenance department. See Luis Osin, "A Computerized Learning Environment Integrating Prescribed and Free Student Activities," Proceedings of the East-West Conference on Emerging Computer Technologies in Education, Moscow, April 1992; Centre for Educational Technology, "Annual Report," November 1992, Tel Aviv, Israel. Also see Trish Stoddart and Dale Niederhauser, "Technology and Educational Change," *Computers in Schools* 9(2/3) 1993, pp 5-22.

[20] Karen Sheingold and Martha Hadley, "Accomplished Teachers: Integrating Computers into Classroom Practice" (Center for Technology in Education: Bank Street College of Education, September 1990), pp. 1, 13.; Also see Decker Walker, Bruce Keepes, and George Chang, "Computers in California High Schools: Implications for Teacher Education," (unpublished paper, 1991) and their designation of teachers who were "pioneers."

[21] As I said earlier, "predicting" walks the thin line between risk and foolishness but, for purposes of prodding discussion, I will do so. In doing so, I assume that no major political, economic, or social trauma dramatically alters popular perceptions about the expected role or organization of schools in this culture. Were a serious political upheaval in the national government to occur, a severe economic depression, or grave urban disturbances requiring sustained military intervention, popular views of what schools ought to do would probably alter and calls for fundamental changes in the purposes and organization of schools would ensue. Under such conditions, the notion of "likely scenarios" would be foolish.

will remain exceptions and, in time, will probably disappear as the next generation of technology, invariably cheaper and improved, comes of age. Thus, although such schools exist now, I find it unlikely for two reasons that they will spread within districts or to most other schools.

First, technophiles typically underestimate the influence of the age-graded school organization in shaping teachers' workplace routines. Furthermore, they often minimize the power of social beliefs that have endured for centuries and perform important functions in society. Beliefs that teaching is telling, learning is listening, knowledge is subject matter taught by teachers and books, and the teacher-student relationship is crucial to any learning dominate much popular and practitioner thinking. Most parents expect their schools to reflect those centuries-old beliefs.

In not paying much attention to the age-graded school, technophiles fail to see how this century-old form of school organization shapes classroom practice with its self-contained classrooms separating teachers from one another, a curriculum divided into segments of knowledge and skills distributed grade by grade to students, and a schedule that brings students and teachers together to work for brief periods of time. These structures, profoundly influencing how teacher teach, how students learn, and the relationships between adults and children in each classroom are especially difficult to alter after a century of popular and practitioner acceptance. Because of these factors, school practitioners have learned how to tailor technological innovations to fit the contours of the age-graded school and the self-contained classroom. For the most part, technophiles disregard these beliefs and organizational traditions.

Second, previous experiences of instructional television, language laboratories, and programmed learning in the 1960s and 1970s suggest caution to policymakers. Districts built new schools, purchased and installed hardware for those technologies. In less than a decade administrators found that the machinery was either unused by teachers, obsolete, or could not be repaired after breakdowns.[22]

These reasons suggest strongly that districts will be reluctant to make major investments in new hardware beyond a model program or demonstration school. Thus, the technophile's scenario is least likely to occur.

HOW LIKELY ARE THE PRESERVATIONIST AND CAUTIOUS OPTIMIST SCENARIOS?

The other two scenarios are most likely to occur but there are important differences between them. Both are basically the same story of modest computer use in schools, but each scenario stresses different facts and, from them, derives entirely different meanings.

Preservationists argue that schools are durable institutions, taking any new technology and tailoring it to fit millennia-old social beliefs about the nature of teaching, learning, and knowledge. Thus, when IBMs and Apples appear in schools they get drafted to continue what is deemed important. Even when a few teachers creatively use computers, preservationists acknowledge such pioneers but see them as mutants, exceptions far removed from the evolutionary trajectory of technology in schools.

Preservationists also point out how the popular age-graded school not only persists through reform after reform but offers many advantages for a democracy seeking to educate millions of students from diverse backgrounds. Such schools have moved wave after wave of immigrants through a system with much-admired efficiency, preservationists argue. Such schools have learned to customize technological innovations to fit the contours of the age-graded school and its self-contained classroom. Thus, this scenario will continue for the immediate future, given the power of social beliefs and organizational forms.

[22] Cuban, op. cit., footnote 1, pp. 27-50.

Cautious optimists, however, reinterpret the same facts, giving them a breezy, sunny-day spin. The optimists' version of the story displays much patience with the time that it will take to make schools technologically modern. Conceding that there are many instances of technologies being used to reinforce existing practices, optimists shift their attention to the slow growth of technological hybrids, those creative teacher mixes of the old and the new in schools and classrooms.

Optimists point to hybrids of teacher-centered and student-centered instruction and see them as the leading edge of an evolving movement—rather than mutants—that eventually will bring schools more in sync with the technological imperatives of the larger society. These hybrids of teacher-centered and student-centered instruction, the optimists say, are early signs of the near and vital future, not instances of powerful machines being used for trivial purposes. Thus, the current reasons for the fumbling incorporation of high-tech machinery into schools—e.g., not enough money to buy machines, teacher resistance, inadequate preparation of teachers, and little administrative support—gradually will evaporate as the hybrids slowly spread and take hold. It is an evolutionary scenario using a clock that measures time by decades rather than years.

If preservationists assume the familiar realities of popular beliefs about schooling and age-graded schools as permanent and make straight-line projections into the future, prudent optimists recognize that these familiar realities continually undergo imperceptible changes. They acknowledge that the age-graded school needs to be transformed into a more flexible, ungraded, collaborative organization. They see it occurring steadily albeit at a glacial pace. All of the hybrids of teacher-centered and student-centered instruction that optimists point to with pride reveal teachers working differently with their students, more as coaches and helpers, and, in doing so, ever so slightly altering school structures.

Finally, optimists know that schools adapt every innovation to fit organizational imperatives, but they also know that administrators and teachers have brought new technologies into classrooms after putting their fingerprints on them. These practitioner-made hybrids are instances, optimists argue, of the power of practitioners to alter their circumstances and make students grin rather than groan over school work.

WHICH SCENARIO IS MOST LIKELY?

I argue that the preservationist's scenario will continue in the immediate future for high schools, and the cautious optimist's scenario will emerge for elementary schools. My evidence for both scenarios occurring at different levels of schooling derives from how schools are organized for instruction at the two different levels and my studies of how teachers have taught over the last century.

Public elementary and secondary schools differ markedly in the complexity of content students face in classrooms, teachers' formal training, allocation of time to instruction, and external arrangements imposed upon both levels from other institutions.[23]

Children in elementary grades learn basic verbal, writing, reading, and math skills. Content is secondary and often used as a flexible vehicle for teaching skills. But in the upper grades of elementary school, and certainly in high school, not only are more sophisticated skills required of students,

[23] Note that I use the phrase "secondary schools." In doing so, I refer to both middle (or junior) and high schools. I draw sharp distinctions between elementary and high school because the structures, roles, and teacher cultures are obviously different. For those middle schools that have embarked on fundamental changes, i.e., eliminated departments, created interdisciplinary teaching teams, teacher advisers, and large blocks of time where students and teachers work together, then they have recreated an elementary-like school. For such middle schools, what I say about elementary schools applies. Many middle schools, however, have adopted only one or two of these reforms and still resemble a junior high school or a miniature version of senior high school. Such places, then, would be counted in my analysis of high schools. See Larry Cuban, "Why Reforms Last: The Case of the Junior High," *American Educational Research Journal*, summer 1992.

but these skills are embedded in complex subject matter that in and of itself must be learned. Literary criticism, historical analysis, solving advanced math problems, quantitative analysis in chemistry—all require knowledge of complex facts and their applications. High school teachers, therefore, university-trained in subject matter, often turn to didactic methods because content often drives classroom teaching practices.

Also, student and teacher contact time differ markedly at both levels. While the self-contained classroom remains the dominant form of delivering instruction at both levels, elementary school teachers generally spend five or more hours with the same 25 or more students. They see far more of a child's strengths, limitations, capacities, and achievements than a high school teacher who sees five groups of 25 students less than an hour a day. Over a nine-month school year, the elementary school teacher sees her 25 children nearly 1,000 hours; a high school teacher sees 125 students about 200 hours in class during the year, or about one-fifth of the time that elementary school colleagues spend with pupils. Contact time becomes an important variable in considering organizational issues of grouping, providing individual attention, varying classroom tasks and activities, and rearranging furniture.

In elementary schools, the *potential* to make organizational changes in these and other areas is present because the teacher has more contact time with the same children than high school teachers do with their students. Whether such changes occur in the lower grades is, of course, an entirely separate issue, but the organizational difference in allocation of instructional time allows for changes in elementary school classrooms.

Finally, external pressures from accrediting associations, college entrance requirements, and job market qualifications have a far more direct, unrelenting influence on high schools than on lower grade classrooms. In the high school, strong pressures on teachers and students derive from meeting the demands of Carnegie units, College Boards, Scholastic Aptitude, Advanced Placement, state and national standardized achievement exams, certifying agencies, and other external constraints.

While some urgencies press teachers and students in the lower grades, especially in getting students ready for the upper grades, flexible responses are possible. Grades (e.g., fourth and fifth) can be merged. Groups within a class can include a range of ages and performance. Whole days and even weeks can be set aside for special concentration in academics or other events. Not so in high schools.

These four structural differences—emphasis on subject matter, teachers' prior training, contact time, and external pressures—may well account for why I found many shifts in elementary school teaching practices and fewer changes in high school classrooms.

My research into how high school teachers have taught subject matter since the 1890s clearly supports the preservationist's story. High school teachers, bound by a social organization of instruction that includes teaching two or three different subjects and seeing 150 to 200 students daily in five or more 50-minute classes, have created a durable, practical pedagogy that researchers have documented consistently in English, history, science, and math over the last century.[24]

In elementary school classrooms, I also found evidence of this practical pedagogy but I also found strong evidence of substantial changes in teaching practices that resembled the hybrids that optimists identified. I found, for example, that in the 1890s, the one form of grouping for instruction in both elementary and secondary school classrooms was teaching the entire group of students at the same time; within three decades, under the insistent pressure of progressive educators,

[24] Cuban, *How Teachers Taught*, op. cit., footnote 6; Also see Ernest Boyer, *High School* (New York, NY: Harper and Row, 1983) Theodore Sizer, *Horace's Compromise* (Boston, MA: Houghton-Mifflin, 1984), and Arthur Powell, Eleanor Farrar, and David Cohen, *The Shopping Mall High School* (Boston, MA: Houghton-Mifflin, 1985).

newer forms of grouping began to appear in elementary schools to teach reading and math. A growing array of instructional materials made it possible for teachers to tailor teaching to student differences. A century later, elementary school teachers routinely use a mix of whole-group, small group, and individual options in their classrooms. While some high school teachers do use varied groupings in their classes, dominant practice remains teaching the entire whole group for fifty-minute periods.

Also teachers' repertoire of classroom practices have broadened over the last century. In the 1890s, lecturing, using the textbook, questioning students on what they know, assigning homework, and tests were the primary tools of the classroom teacher. A century later, these tools persist as standard practice in secondary school academic subjects. In elementary schools, however, that teaching repertoire has expanded with the addition of visits to community institutions, new materials and technologies. While field trips, films, videocassettes, television, and computer labs may not yet be mainstays of most classroom instruction, they testify to the slow growth of instructional hybrids. Such instances of changes in classroom practice provide additional evidence for the cautious optimist's scenario of technological hybrids slowly changing the conduct of schooling.[25]

The point that I wish to make is that how the age-graded school is organized for instruction at the two levels determines to a large degree which scenario will most likely occur. The preservationist's scenario is most likely in high schools where academic subjects reign, teachers' training was in disciplinary content, and the number of classes and students teachers teach remain high. The cautious optimist's scenario is more likely to occur in elementary schools where organizational differences make shifts in practice possible and where hybrids of teacher-centered and student-centered instruction have, indeed, evolved slowly over the last century.[26]

There are, however, emerging national policies that may influence both the pace and direction of these scenarios materializing in the 1990s. One is the current movement (and legislation) for national goals, standards, and testing. If the movement continues its momentum, especially in its concentration on national examinations with strong consequences for individual students' futures and school funding, the movement may largely channel new technologies to fit existing patterns of teaching and learning because what fuels the drive

[25] Cuban, *How Teachers Taught*, op. cit., footnote 6, pp. 135-136; 199-200.

[26] One way to assess this prediction of what will occur in high schools, for example, is to compare the penetration of computers into college and university classrooms. High school teachers are much closer to college professors in their training and allegiance to subject matter than elementary school teachers. Hence, one would expect, given my interpretation, that professors would use computers for their classroom teaching about as much as high school teachers, which would be less than elementary ones.

While there is much evidence that individual professors across most disciplines, including the humanities, have adapted with gusto the use of the computer for their writing (as word processors), research (for statistical analysis), and communication (e-mail, internet bulletin boards) there is much less evidence that in their weekly teaching the presence of the computer has altered traditional lectures or seminars. See Donald R. McNeil, "Technology in College: Where Is the Impact?" *The Chronicle of Higher Education*, June 7, 1989, p. A44; Robert Jacobson, "As Instructional Technology Proliferates, Skeptics Seek Hard Evidence of Its Value," *The Chronicle of Higher Education*, May 5, 1993, p. A27. In a survey of its 32,000 members, the Modern Language Association found extensive computer usage among its English and foreign language professors in preparing manuscripts (95 percent) and routine correspondence (84 percent). Almost 80 percent said they used the computer to prepare teaching materials. But there was no category for responses of whether professors used computers in classroom instruction—an amazing omission. See *The Chronicle of Higher Education*, Apr. 21, 1993, p. A27. Stanford University Professor Patrick Suppes, an early advocate of computer-assisted instruction in the 1960s and a teacher whose courses in logic and math were taught wholly by computer in the 1970s and 1980s answered a reporter's question about the future impact of the machine on teaching at Stanford by saying it would be "substantial over the next half-century." When the reporter expressed surprise at the length of time, Suppes replied: "[T]he actual structure of universities is extraordinarily conservative." The Stanford University *Campus Report*, Jan. 12, 1994, p. 4. In short, for all the organizational and governance differences between colleges and high schools, there is a striking similarity in the limited use of computers in both sets of classrooms.

toward national goals, standards, and testing is the lure of increased student productivity. Concentration on quantitative standards reinforced by high-stake test results usually diminish practitioners' appetites for taking risks in classroom and school innovations. My guess would be that continued national pressure would bolster the preservationist's scenario for *both* elementary and high schools, while limiting innovations in information technologies that might not meet the standard of higher test scores such as the ones pushed by neoprogressive reformers.

SUMMARY

With all the talk of school reform and computers over the last decade, why has electronic technology been used far less on a daily basis in classrooms than in other organizations? My answer is that schools are different from those organizations in which telecommunications have spread swiftly. Moreover, technological innovations never have been central to any national movement to improve schooling since the origins of public schools a century and a half ago. Not until the 1980s and 1990s have new technologies been part of the rhetoric of reform. Yet after all has been said and done, more has been said than done.

The seemingly marginal use of computers and telecommunications in schools and classrooms is due less to inadequate funds, unprepared teachers, and indifferent administrators than it is due to dominant social beliefs about what teaching, learning, and proper knowledge are and how schools are organized for instruction.

There are at least three plausible stories for what the next decade holds in store for teachers' use of computers. The likely scenarios point to little substantial change in the closing years of the 20th century. Where two scenarios differ is that cautious optimists see hope in the hybrids that have emerged, a hope that over the ensuing decades these hybrids will become routine, producing significantly different classrooms and schools; preservationists see far more stability than change in the years to come, with teaching and learning staying pretty much as it currently is. The most likely scenario is the one predicting slow but dynamic changes in both teaching and school structures that will occur as more hybrids of old and new forms of instruction are merged with the next generation of computers. Those changes will seem glacially slow to impatient reformers but, perhaps, just the right pace for those aware of the complexities of changing unique places called schools.

APPENDIX E REFERENCES

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Appendix F Contractor Reports

F

Copies of contractor reports prepared for this study are available through the National Technical Information Service, either by mail (U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161) or by calling NTIS directly at (703) 487-4650.

Appendix A

James Bosco, Western Michigan University, "Schooling and Learning in an Information Society," November 1994, NTIS No. 95-172227.

Appendix B

Beverly Hunter and Bruce Goldberg, Bolt Beranek and Newman, Inc., "Learning and Teaching in 2004: The Big Dig," December 1994, NTIS No. 95-171005.

Appendix C

Margaret Riel, Interlearn, "The Future of Teaching,"November 1994, NTIS No. 95-172219.

Appendix D

Robert Kozma and Wayne Grant, Center for Technology in Learning, SRI International, "Year 2005: Using Technology to Build Communities of Understanding," November 1994, NTIS No. 95-172235.

Appendix E

Larry Cuban, Stanford University, "Public School Teachers Using Machines in the Next Decade," October 1994, NTIS No. 95-172243.