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ABSTRACT

This book provides information for integrating technology into teaching and learning in K-12 schools. The information is based upon findings from two past programs of the National Foundation for the Improvement of Education. "The Road Ahead" program explored how technology can facilitate teaching and learning in both formal and informal education settings, and the "Learning Tomorrow" program funded pilot projects that investigated how technology can improve teaching and learning for underserved students. Evaluative data from the experiences of the 32 teams of teachers, administrators, and community-based partners that participated in "The Road Ahead" and "Learning Tomorrow" programs are major sources of information. The book consists of a general summary of findings from "The Road Ahead" program, followed by six papers on major topics of interest in integrating technology into teaching and learning: "Information Technologies in Education: A Survey of Uses and Issues"; "Project-Based Learning and Information Technologies"; "Assessment and Information Technologies in the K-12 Curriculum"; "Professional Development and Information Technologies"; "At-Risk Students: Technology's Particular Promise"; and "School-Home-Community Learning Connections: Roles of Information Technologies." Each paper contains an annotated bibliography. (AEF)

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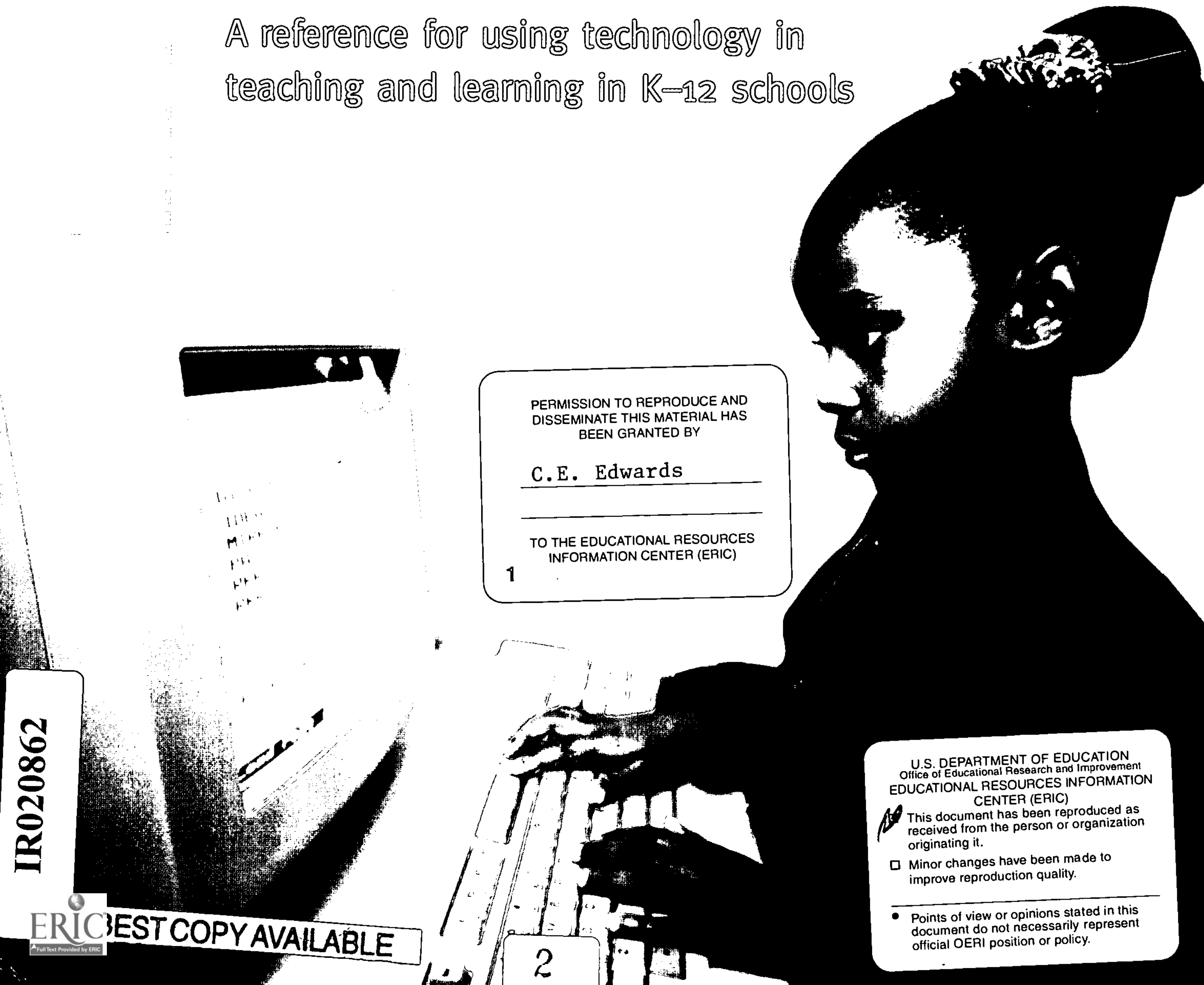

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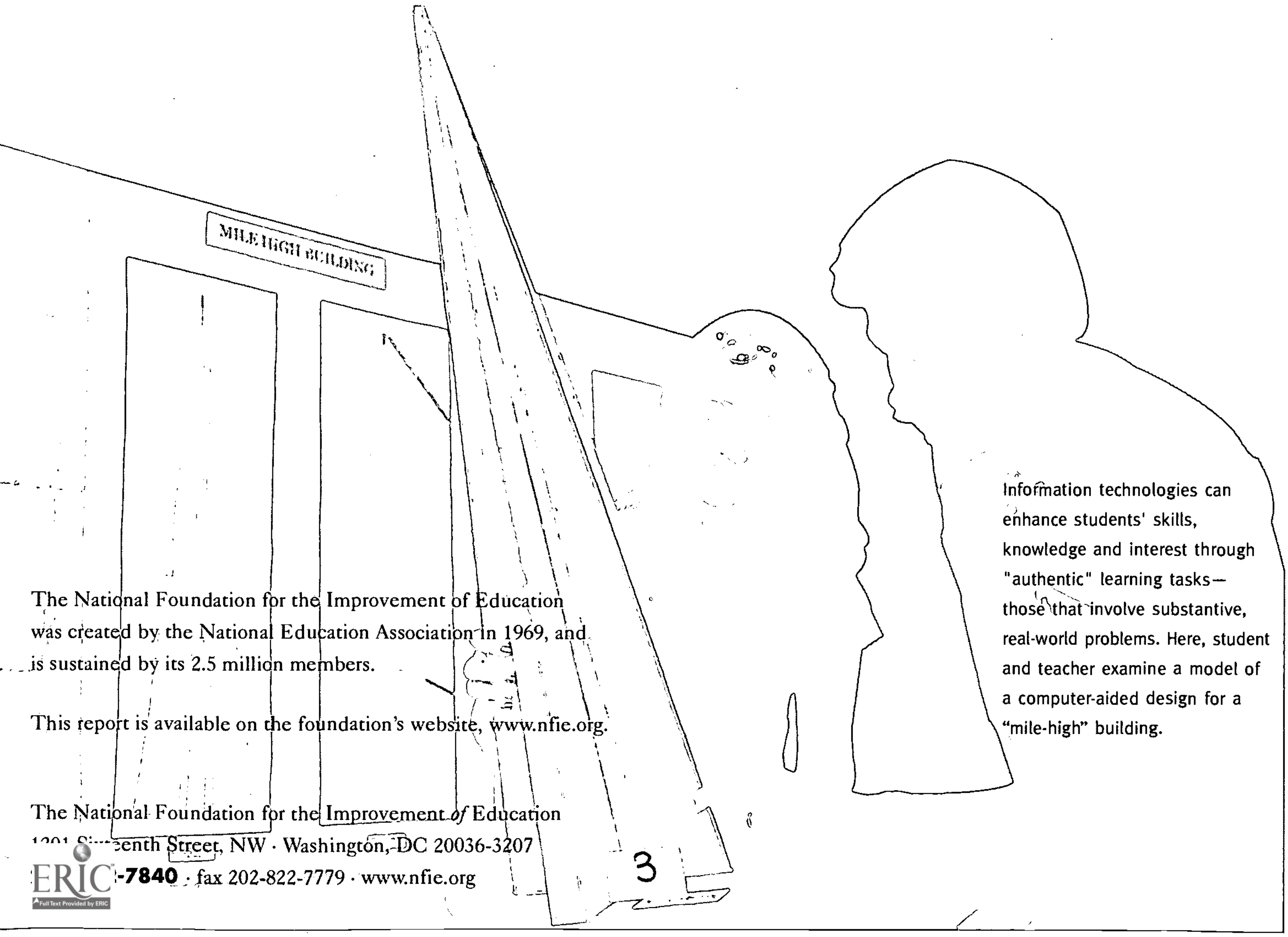

Information technologies can enhance students' skills, knowledge and interest through "authentic" learning tasks—those that involve substantive, real-world problems. Here, student and teacher examine a model of a computer-aided design for a "mile-high" building.

The National Foundation for the Improvement of Education was created by the National Education Association in 1969, and is sustained by its 2.5 million members.

This report is available on the foundation's website, www.nfie.org.

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Connecting the Bits is available on the foundation's website, www.nfie.org, along with information about NFIE's additional professional development work.

Connecting the Bits

A reference for using technology in teaching and learning in K–12 schools

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Purpose and Sources

Connecting the Bits provides information for integrating technology into teaching and learning in K–12 schools. The information is based upon findings from two past programs of the National Foundation for the Improvement of Education:

The Road Ahead program explored how technology can facilitate teaching and learning in both formal and informal education settings. Twenty-two sites across the country created school-community partnerships. The sites reflected a full range of technology experience, from elementary students' first computer use to high school students' commercial quality multimedia presentations. *The Road Ahead* program was supported by Bill Gates, chairman of the Microsoft Corporation, with proceeds from his book, *The Road Ahead.*

The *Learning Tomorrow* program funded pilot projects that investigated how technology can improve teaching and learning for underserved students. The program supported teachers' professional development, examined how technology can meet diverse student learning needs, and engaged students in real-world learning activities. *Learning Tomorrow* was supported by the Sega Foundation of America and the AT&T Foundation.

Evaluative data from the experiences of the thirty-two teams of teachers, administrators, and community-based partners that participated in *The Road Ahead* and *Learning Tomorrow* programs are major sources of information for *Connecting the Bits.*

Primary Audiences and Suggested Uses

Connecting the Bits is principally addressed to educators, including teachers, administrators, technology coordinators, media specialists, paraprofessionals, higher education faculty, and curriculum specialists.

Connecting the Bits may also provide useful information to informal educators, including librarians, museum staff, community computer center staff, the staff of other community-based organizations, parents and educational policy makers, including school boards, chief state school officers, and legislators.

Connecting the Bits addresses some of the recommended approaches to student learning that are often used with educational technology. Network technicians and administrators based in schools or districts that want to learn more about these approaches will also find this report helpful.

Both novice and experienced educational technology users will benefit from the report.

School and district technology planners will be interested to note that *Connecting the Bits* provides valuable information about "best practices" in integrating technology, which can serve as a guide for technology planning.

Teacher study groups may wish to read and discuss the report, providing examples from their own classrooms, schools, and districts. *Connecting the Bits* may also serve as background reading for teacher action research.

The report may suggest roles that parents can play in supporting technology in education; for example, as members of technology site councils, teacher-parent study groups, or rubric development committees.

Administrators and technology coordinators may employ the report to aid in meshing hardware and software planning with instructional goals and budgetary priorities. Media specialists and school technology coordinators may find it helpful in coordinating with classroom teachers and administrators in subject matter, program planning, and hardware and software support.

These suggestions are not exhaustive. They are only meant to serve as examples, and to be helpful in generating additional uses and audiences.

Recommendations for Readers

Connecting the Bits consists of a general summary of findings from *The Road Ahead* program, followed by six papers on major topics of interest in integrating technology into teaching and learning. Each paper contains an annotated bibliography.

"Lessons from *The Road Ahead*" will be of value in providing research-based information about the use of technology in schools to the general public and to lay audiences for whom the subject is of broad interest. Those who are well-versed in educational technology may wish to skim "Lessons from *The Road Ahead*" or begin their reading at any section of the report, as each paper may stand alone or may be used in conjunction with any or all of the others.

"Information Technologies in Education: A Survey of Uses and Issues" is intended for readers who are new to technology and its use in teaching and learning. Experienced educational technology users may choose not to read this paper or merely to review its contents.

Information about NFIE

The National Foundation for the Improvement of Education empowers public education employees to innovate, take risks, and become agents for change to improve teaching and learning in our society. As the foundation of the National Education Association, NFIE believes that all students can learn and that quality education begins with teachers.

NFIE's work is rooted in the belief that teachers' professional development is a cornerstone of reforms that heighten student achievement. The foundation helps teachers to take responsibility for the quality of the profession; play a leadership role in the development of research and policy affecting public education; and acquire skills, knowledge, and experience that contribute to student success.

Acknowledgements

The National Foundation for the Improvement of Education wishes to thank several individuals for their important contributions to these papers.

Carol Edwards, director of programs, NFIE, who conceived of and directed the production of *Connecting the Bits*.

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Nancy Kober, independent consultant, who edited *Connecting the Bits*.

Terry Baker, Jan Hawkins, and Gale Justin of the Center for Children and Technology, Education Development Center, evaluators for the *Learning Tomorrow* program, whose evaluation findings contributed significantly to "At-Risk Students: Technology's Particular Promise."

Nancy Carson of NCAssociates, consultant for *The Road Ahead* program, who wrote "Lessons from *The Road Ahead*" and "At-Risk Students: Technology's Particular Promise."

Judy Hodgson, past director of institutional advancement; Anna Smith, administrative assistant for institutional advancement; and Kathryn Willis, communications officer: NFIE staff who contributed significantly to the production of *Connecting the Bits*.

We wish to thank the board of directors of the International Society of Technology in Education for their valued support.

The Road Ahead program was funded by Bill Gates, chairman of the Microsoft Corporation, with proceeds from his book, *The Road Ahead*.

Additional support for *The Road Ahead* program was provided by the Compaq Comuter Corporation.

The *Learning Tomorrow* program was funded in part by the Sega Foundation of America and by the AT&T Foundation.

Additional support for the *Learning Tomorrow* program was provided by Apple Computer.

We also extend our thanks to NFIE's founder, the National Education Association and its 2.5 million members whose support continues to sustain the foundation.

Lessons from *The Road Ahead*: An Educational Technology Program of the National Foundation for the Improvement of Education

Today, almost every school in America is connected to the Internet. Increasingly, individual classrooms across the country have their own access to the rich resources of the information superhighway. What is more, this remarkable accomplishment has been achieved with amazing speed.

In 1995 the World Wide Web was a new concept, and technology was slowly making its way into education. Teachers were struggling, often alone, to figure out how hardware and software—often balky and unreliable—could improve student learning.

As the Internet grew from a military and academic research tool to a broad-based network of resources and communications, it significantly increased the potential for contributing to improved student achievement. The Internet increased the need for insights into integrating technology into the curriculum, providing a clear mandate for educational professionals and technology experts to collaborate.

To that end, the National Foundation for the Improvement of Education and Microsoft created *The Road Ahead*. The collaborative program focused on student-centered activities to demonstrate how multimedia and telecommunications technologies could facilitate both formal and informal teaching and learning.

The Road Ahead

The mission of *The Road Ahead* program was to help teachers develop and implement multidisciplinary initiatives that went beyond traditional teaching. The goal was to learn lessons that all teachers and students could apply in developing an understanding of what a "connected learning community" might really mean. In response to a request for proposals, NFIE received 348 applications and selected twenty-two projects in fifteen states. The program was supported by Bill Gates, chairman of Microsoft, Inc., with the proceeds from his book, *The Road Ahead.*

Twenty-two pilot *Road Ahead* projects

Each school site team and a community partner set out to test the new concepts and integrate new resources into the classroom and informal learning settings. Each site worked with a different configuration of technology and set of objectives. Each project had its own plan as well as particular methods for integrating technology into teaching. Projects ranged from learning local history in cooperation with a senior citizen center to developing environmental programs and reclaiming waterways. Schools partnered with museums, libraries, research centers, and community-based organizations.

NFIE and Microsoft designated six essential components for the projects. These were

Essential components of the pilot projects

- **school-community partnerships developed by five-member teams that included at least one public school teacher, an administrator, and a representative from a community-based organization, including libraries and museums;**
- **$30,000 spread over two years;**
- **three NFIE-sponsored professional development conferences;**
- **twenty-two teacher mentors, with backgrounds relevant to specific sites;**
- **an educator-moderated online network to facilitate communications;**
- **a large amount of Microsoft software and two Compaq computers.**

The experiences that occurred as sites combined technology, teaching and learning, partnership-building, professional development, and technical support gave rise to several clear conclusions. Based on *The Road Ahead*, NFIE makes the following recommendations in designing a technology-based effort:

Conclusions and recommendations from the pilot projects

- **Start with what you want to achieve. Let desired student outcomes guide technology selection and use. Clear academic goals should govern, so that the focus is on outcomes and achievements rather than on dazzling technological tools.**

- **Innovative programs need three to five years to show results.**

- **Investment in technology requires investment in professional development, continuing teacher-defined and teacher-led training, and student-led training.**

- **Technology supports critical thinking, which should be a focus of the effort.**

- **Success requires the involvement of many stakeholders, the inclusion of administrators at every step of the way, and the work of experienced teams for systemic and long-term planning.**

The Road Ahead program results are a strong endorsement of technology as a worthwhile investment for public education. The results also emphasize that simply placing computers in classrooms does not guarantee improved student achievement. This brief overview discusses many of the outcomes of *The Road Ahead* and highlights those lessons that are critical for program success.

Student Learning

The object of technology-based teaching is improved student learning. Results of *The Road Ahead* for students, as documented by the program's evaluator, the International Society for Technology in Education (ISTE), included

Improved student learning is goal

- **increased technology capability and skill;**
- **a surprisingly strong emergence of students as teachers;**
- **increased motivation for learning (focused around the introduction and initial use of technology);**
- **improved achievement in core subjects as measured by test scores in some cases, and grades or student products in other cases.**

Project-based; team-based; aimed at higher-order skills

The types of learning that information technologies can support—project-based and team-based (both aimed at critical thinking skills)—become better understood. Traditional, lecture-based classroom roles are changing, as educators and students work collaboratively in more open-ended teaching and learning experiences. This combination of elements can sometimes transform uninvolved, at-risk students into active and invested learners. This motivational aspect of technology is a principal reason that educators try so hard to master and apply technology tools.

At Nelson Middle School in Renton, Washington, both teachers and students needed to learn new technology skills. Nelson defined this as an opportunity and created an after-school program where students and teachers learned alongside each other in formal training sessions and less structured activities. On certain nights of the week, the facility was open to parents, who both learned from and taught their children.

Students gain access to resources via the Internet. Software tools offer a variety of ways to manipulate these resources. Just as in business and higher education, schools suddenly can connect with information, data, and visual and audio materials in ways never before possible. This extraordinary expansion of the classroom and the interactive nature of finding and using information mean that the world can become the curriculum.

Expanded curriculum; increased motivation

Motivation for learning is reinforced and students also come to terms with analyzing materials, comparing and contrasting ideas, using induction and deduction, synthesizing information, and taking informed action. Thus, project-based learning using Internet resources can jump-start even young students, effectively giving them tools once available only to scholars and researchers. By working in teams to create multimedia projects based on selected sources, students become better prepared for the modern world of work.

Working with technology also enables parents to understand their children's achievements and assess their progress more easily. Because of the variety of products and projects that engage students through technology, specific skills can be identified and encouraged. These include interpretation and manipulation of data, development of verbal and mathematical skills, and visual and graphic capability.

At Longfellow Elementary in Eau Claire, Wisconsin, third graders, many from the growing Hmong community, joined forces with senior citizens to learn the history of their country and create a hyperstack resource on local history, geography, and resources. Student enthusiasm and skill skyrocketed. By the end of the project, the students were conducting presentations for the Board of Education, and some of the most effective presenters were students who had seldom participated in class work.

Parental involvement and support

What is more, parents can support their children's learning in many ways. They can connect directly into homework hotlines, check on assignments, contact the teacher, and even view what is happening in schools. Parental involvement and support for schoolwork can be as transformed as student learning.

Students as teachers

Finally, because of the ease with which young people master the operation of new technology, students are sometimes able to teach their teachers. The way that students and teachers teach and learn together when they use technology in schools is good practice for the adult world of work, which increasingly requires diverse individuals to work effectively in teams. Students learn to deal directly with adults in schools and in the community and to be part of a world that is becoming a community of learners.

Professional Development

The key to effective use of technology in schools is professional development.

As *The Road Ahead* program began, it was already clear that few schools were making the level of commitment to professional development that would be necessary. In 1995 the Congressional Office of Technology Assessment stated that in any school technology effort, at least one-third of total cost should be designated for professional development. Professional development was not only underfunded, but also the old models were not working. One-day workshops on the conceptual aspects of computers, training on generic technology, and training focused on hardware operations were simply not effective for integrating technology in ways that resulted in improved student learning.

At least one-third of funds for professional development

The Road Ahead projects devoted, on average, 36 percent of their budgets to professional development and related staffing, such as substitutes. Intensive and continuing professional development was a hallmark of the program, and site teams credited this investment as crucial. NFIE directly provided the equivalent of nineteen days of training and workshops, a professional development investment roughly comparable to a three credit-hour graduate course.

The dominant site model of professional development was teachers teaching teachers. Staff-run, hands-on workshops, classroom demonstrations, and just-in-time help sessions were frequent. The teams learned together and supported one another steadily. They trained on the equipment they were using and learned by developing their own products, approaches, and methods. Because they worked closely and became so comfortable with technology, some *Road Ahead* team members eventually became technology leaders for their school districts.

Teacher teams and a focus on practical applications

Both peer-coaching and supporting students as trainers strengthened professional development at all the sites. New skills were learned when needed and were reinforced through daily use. The focus was always on practical applications. As projects grew and involved other classrooms, *The Road Ahead* teams obtained "buy-in" from other educators by sharing skills and knowledge. In fact, the constantly changing nature of modern technology means that there is always something new to learn, so old barriers of "who knows" and "who learns" simply dissolve. Everyone is eventually in both categories.

Online mentoring worked extremely well in a few cases, moderately well with regard to early plans and strategies in many cases, and not at all in others. A clear finding from this experiment is that while online mentoring can be efficient and extend resources, the mentor must establish some personal relationship to the project team and the site through visits. Help is more easily given and received when people have connected in the real world.

Online mentoring: successful when paired with personal contact

Teachers at Rice Creek Elementary in Columbia, South Carolina, wanted an in-depth course at the start, not short workshops. A professor from the University of South Carolina agreed to teach a graduate-level course in the Rice Creek computer lab, where twenty-five people met weekly for three hours. The Rice Creek team defined this event as creating "the critical mass of trained teachers who supported each other." Rice Creek's principal, who was in the class, gained credibility as a leader and as a man who made good on his commitment.

Technology Issues

Professional development is the key to effective technology use, but there are even more fundamental requirements: The technology must be in place; it must be connected; and it must work.

Technology system support: crucial at both building and district levels

As *Road Ahead* projects moved to implementation in the fall of 1995, each project had designed a technology system and planned its use. In more than one school, however, extraordinary delays meant that projects fell far behind. Vendors failed to produce promised software that would support in-school networks. School districts changed leadership, encountered budget problems, or for other reasons did not meet long-standing deadlines for installing equipment. Difficulties with local service providers made Internet connections seem like a dream.

At some sites, technology was installed, but keeping it in operating condition was a constant drain on the project. From the early period of vendor-provided technical support, most school districts have moved to hiring their own support personnel, and some schools have done the same. Increasingly, students are taking the lead in providing technical support for maintenance and upgrading.

Difficulties with technology underscore the necessity for having building and district leadership commitment. Some *Road Ahead* schools were able to recruit their district superintendents for the NFIE summer intensive programs. This level of participation translated into strong support for projects. Although technology is evolving rapidly and becoming easier to use, it is still difficult for a classroom or a school to try and go it alone.

At Romig Junior High in Anchorage, Alaska, plans were delayed a year due to changes and barriers in district technology policy and the failure of software chosen to support the computer pen pal component, despite many attempts to make it work. Changes in admission at the partner senior citizens' home increased the proportion of residents with advanced dementia. The team persevered and overcame these difficulties.

Once the technology is installed and working, professional development must be available, as discussed above, but beyond training, teachers and teams must work together to develop a base of experience for integrating technology into teaching. While easy to describe, this integration is not easy to achieve. Trial and error, relearning, and redefining characterize *The Road Ahead* experience.

Fortunately, this experience is cumulative, and as teams developed knowledge, they were able to create better and better techniques. This level of experience, plus the newness of the strategy, is one reason that technology efforts must be understood as part of a long-term commitment. If the expectation is that a school will go from zero to integrated learning in a year or so, with provable results in student achievement, the expectation is unrealistic.

Integrated learning requires long-term commitment

Systemic Change

Technology changes the conditions of teaching and learning. Based on *The Road Ahead* projects, two years of intensive work at twenty-two sites covering a wide range of students, technologies, and projects, NFIE can identify some aspects of schooling that fall into the category of systemic change.

In this instance systemic change means two things: In order to use technology well, these changes will be necessary; and if technology is used well, these changes will be inevitable.

Effective use of technology and systemic changes are mutual and simultaneous

Time

Time has long been a major concern for educators. There is never enough time for planning, teaching, assessing, revising, and implementing. It is impossible to put technology into the classroom effectively without allotting substantial amounts of time for team training and other types of professional development.

Additional time, flexible scheduling necessary

Road Ahead schools opened blocks of time by shifting school hours, scheduling late openings, employing substitutes extensively, and allowing teachers to travel and work together. Even with major adjustments in scheduling for professional development, teachers still worked very long hours and gave massive amounts of uncompensated time.

Technology allows for delivery of extraordinary resources, but it also requires much time and effort. Technology often becomes an incentive for block scheduling or some other reorganization of the school schedule, so that longer instructional periods become available for teamwork and project efforts that need sustained concentration.

Roles

Changing roles: teachers as coaches and facilitators; students as directors of their own learning

Teachers acquire new roles as they use technology. They naturally move toward the roles of coach, facilitator, and mentor, as more of the resources for learning become directly available to students.

Teachers are no longer required to provide all the information and knowledge that students need. Teachers continue to nurture and guide students, but they do it in a different way. Teachers also increasingly acquire professional skills desired by the world outside the classroom, and they become web designers, technology leaders, software designers, and information managers.

Students change roles as well, taking on more responsibility for their own learning and acting as trainers and teachers for other students and for adults. All these changes require sensitivity, the involvement and understanding of parents, and the support of the community.

The team at South Mountain High School in Phoenix, Arizona, held regular staff training sessions after school from 4 to 5 P.M. for eight weeks. The team also gathered every Friday afternoon to stay in touch and encourage one another.

Infrastructure resources

Advances in global internetworking will only increase in pace and in scale. School districts and educational policymakers must prepare for and work toward this, so that schools are not left behind. This change will require online connections for schools, community centers, and other education partners and the provision of resources within schools and among students in an equitable manner. The 1990s computer labs will take a back seat as classrooms are directly linked and well-equipped with workstations, peripherals, and ever-smaller and more powerful equipment.

Districts, parents, and community: partners in technological connections for education

A lesson of *The Road Ahead* program is that educators must work to ensure that school districts take advantage of all means to make these changes, including developing community support, parent involvement, and relationships with businesses and organizations. Means such as the E-rate must be provided and maintained to help those schools in communities where available resources are simply inadequate to serve student needs equitably. Further, school districts, parents, and educators must strive for flexible approaches and solutions to teaching and learning in a world of constant technological change.

The Road Ahead project at Lakeside Elementary in Manistique, Michigan, was a catalyst for tremendous change in the school district and the community. Because of the project,

- all elementary and high schools in the district have installed Internet connections;
- the district is shifting its junior high curriculum to better integrate technology;
- the district has established a technology committee;
- team members have become an important resource for district decision-makers;
- the community has established a Family Tech Center, offering training led by the school staff.

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Conclusion

Information technology as a tool for enhancing teaching and learning can expand the horizons of education around the world to enrich the resources of knowledge. While the promise is great, so, too, is the commitment that is necessary for its realization.

Changing traditional roles

Over time, ample connectivity in every classroom is likely to become a reality. But for ready access to translate into improved student learning, the traditional roles of teaching and learning will need to undergo significant change. Professional development, how and what students are taught, and the very climate and structure of education must be transformed.

Life-long collaborative learning

Lecture-based models should give way to collaborative learning, where knowledge and skills are shared among teachers, students, parents, the community, and beyond. Through project-based learning, students should take an active role in their own learning and increase critical thinking abilities. Learning should become a collaborative, life-long enterprise, as the barriers of "who knows" and "who learns" simply dissolve. At-risk students especially should benefit, as intellectual achievement is driven through problem solving, research, analysis, and synthesis of authentically posed ideas and knowledge. In addition, educators should use technology tools diagnostically to improve student assessment methods.

Necessity of teacher professional development focused on student learning

Teachers must have high-quality, job-embedded professional development, taking on roles as coaches and mentors to their colleagues. Old models of one-shot training workshops will not result in changed attitudes and beliefs about teaching or in desired student outcomes. High-quality professional development

- **must have student learning as its focus;**
- **must be designed and directed by teachers themselves;**
- **must be rigorous, collegial, and extend over time.**

This kind of professional development requires a substantial portion of the overall educational technology dollar.

Integrating technology effectively requires building strong and stable partnerships that include teachers, administrators, parents, and others who share a significant interest in enhanced student learning. The contributions of individuals and groups beyond the classroom become invaluable assets. Businesses, cultural organizations, and higher education institutions extend both the resources and the reach of support.

System-wide change in time allocation, infrastructure, and policy supports

Systemic change ensures that schools have the ability to achieve and sustain educational technology's effectiveness. It is necessary for educators, policy-makers, and public agencies to assure that both infrastructure resources and the necessary policy supports, such as time for professional development, are available. It is also important to build time for coaching, collegial learning, and team training into schedules and to be patient.

Technology efforts are long-term commitments and require at least three to five years to demonstrate increased student performance.

Technology is rich in its potential for preparing today's students for adulthood in the new millennium. Technology is a tool, however, and much work remains in order to achieve the goal of integrating technology effectively into teaching and learning. It is a goal toward which educators must strive, for its attainment holds the promise of readying all America's children in the twenty-first century.

"Lessons from *The Road Ahead*" is one of several papers included in *Connecting the Bits, A reference for using technology in teaching and learning in K–12 schools*, issued by the National Foundation for the Improvement of Education in 2000, and available at www.nfie.org.

Information Technologies in Education: A Survey of Uses and Issues

Introduction

Information technologies, such as computers, telecommunications, and digital cameras, are changing what and how we learn as well as how we work and play. This paper looks at some of the instructional uses of information technologies in K–12 education and broaches some of the critical issues that confront teachers who want to use these technologies effectively.

The Information and Communications Age

We are at the beginning of a major new era, the Information and Communications Age. This era is being propelled in large part by the recent development of technologies that merge print, telecommunications, and computers. Like the emergence of reading and writing or the invention of movable type, the merger of print, telecommunications, graphic design, and computers represents a milestone in the way people accumulate, use, and disseminate knowledge. Two features of these new technologies make them especially promising for reshaping education. First, they greatly speed up the storage, movement, and retrieval of information, allowing people remote access to the libraries of the world. Second, they significantly enhance peoples' capacities to process information and solve problems.

This paper discusses

- the information and communications age: a brief description of its potential for changing education and its challenges;
- scenarios of current uses: the breadth of information technologies in the classroom and the issues raised in their educational application;
- information technologies in education: a summary of types, strengths, and limitations;
- information technologies and standards-based reform: a discussion of their relationship;
- an annotated bibliography.

The "length" of a cyberspace "year" is two to three months

A key characteristic of the Information and Communications Age is its dizzying pace of change. The worldwide total of computer-based information processing power is doubling approximately every two to three years. Fiber optics and wireless networks are blanketing the world, creating information highways that link people across oceans and continents. It is said that in cyberspace—the world of computer networks, the Internet, and the World Wide Web—the "length" of a year is perhaps two to three months. In other words, the pace of change in cyberspace is several times faster than in other sectors of society, such as government and education.

Information technologies have become more commonplace in both formal and informal educational systems. Virtually all students in the United States now have access to computers and other information technologies. In 1998 public schools in the United States had an average of about one microcomputer per every six students. Moreover, about 40 percent of the households in the United States now have a general-purpose microcomputer, with many of their owners reporting that "education" was one of the main reasons why they bought it. Since 1995 both school and home access to microcomputers has increased. By 1998, 51 percent of classrooms had access to the Internet, and access is increasing steadily. Both in school and at home, however, the most economically disadvantaged students and students of color have less access to the Internet than the general population (NTIA 2000).

Technology applications in all levels of education

The merger of print, telecommunications, and computers has advanced to the point that elementary school students are developing multimedia documents—complete with text, sound, graphics, and video—and are distributing them via computer networks. Classrooms of students are designing their own World Wide Web pages and communicating with people around the world. Both students and teachers are learning how to use computer tools as routine aids to problem solving and personal productivity. New interactive systems enable students to ask questions, receive feedback, and explore the implications of various choices.

Challenge:
integrating technology
into instructional programs

The Information and Communications Age also brings new challenges for schools and teachers. Rather than viewing technology as an end in itself, school districts and schools must figure out how to integrate information technologies into their instructional programs. Districts and schools must provide adequate resources for professional development, curriculum development, and technical support for students and teachers, even as they struggle to keep up with the costs of hardware and software that quickly become dated. Teachers must learn how to use technology to promote students' understanding of key concepts within particular subject matter and help them achieve the high standards of learning now being adopted in most states. Teachers must also be prepared to assess students' progress through alternative methods that are compatible with technology-based instruction but may not align easily to standardized accountability measures.

Scenarios of Current Uses

The scenarios below illustrate the breadth of current uses of technology in schools. Following each scenario is a short discussion of some of the issues that must be dealt with to sustain, improve, and effectively integrate technology into education.

Several of the issues raised in these examples are explored in more detail in other papers in this report. These include

- **professional development and information technologies;**
- **assessment and information technologies in the K–12 curriculum;**
- **project-based learning and information technologies;**
- **school-home-community learning connections: roles of information technologies.**

Scenario 1

As part of the social studies curriculum, teams of fourth-grade American students design World Wide Web pages to depict what life is like for children in other countries. Each team uses information from the school's CD-ROMs, the Internet, and print resources available in the school library. This assignment helps students learn how to locate, select, download, and integrate information from multiple sources. The task also gives students practice working together as a team and learning from each other. The students are especially motivated because they know the Web pages they create will become part of their electronic portfolios and will be used by other students—perhaps even students in other countries.

Challenge:
guiding student research skills;
evaluating electronic portfolios

Issues: The quality of information available from different Web sites varies tremendously. Can fourth-grade students learn to differentiate between high-quality and low-quality information? Can they learn to deal with a vast array of sources of information—sources that may well provide contradictory information? How does a teacher assess the work of students who are working in teams, especially if each team is working on a different project? How do students and teachers learn to develop and work with electronic portfolio materials?

Scenario 2

Students in a ninth-grade microcomputer-based laboratory have set up experimental equipment to track a moving object. The tracking device, which is similar to an automatic range finder in a camera, feeds data into a computer. The computer analyzes the data and produces graphs of distance, speed, and velocity. One of the project's activities has students track their own movements and try to move their bodies to produce certain types of graphs.

Challenge:
determining level of students' comprehension of subject rather than students' technology mastery

Issues: The computer system can do computations and analyses that go well beyond the level of mathematics the students have studied. With computer technologies, students can carry out experiments and tackle problems that are far more advanced than what they could do if they had to rely on the knowledge they bring to the task. These kinds of activities present a special challenge to teachers. Sometimes computer-based activities can mask students' understanding or foster misconceptions, making it difficult for the teacher to know whether a student really understands the underlying concepts involved. For example, a ninth-grade student may be able to "do" fractal equations on a computer without really understanding much about fractals.

These activities can still be valuable in familiarizing students with advanced concepts and helping them develop an intuitive understanding that forms a basis for a more sophisticated understanding of those same concepts later on. But teachers must be able to distinguish between tasks that enrich students' understanding and flashy activities that contribute little to students' knowledge.

Scenario 3

A student who has severe physical disabilities communicates using a voice synthesizer, which enables her to pick letters and words using the small amount of movement she has in one hand. She uses this same equipment to write, look up information on CD-ROMs, and communicate by email with friends throughout the world.

Issues: Adaptive technologies can help many physically challenged students function successfully in regular classrooms. These technologies are often new to the teacher, however, and to the school's technology support system. Teachers and other students may need training in how to work with adaptive technologies and how to teach students who rely on them.

Challenge:
student and teacher
training in adaptive technologies

Scenario 4

A sixth-grade class is doing a project on how to preserve and enhance the wetlands. A local surveying company, one of the school's community partners, contributes personnel and equipment for a student field trip to a wetlands area. At the site, the students take digital video and still-camera pictures and record their field observations with tape recorders and laptop computers. Their goal is to develop a video and a hypermedia stack about ways to preserve the wetlands, which they will use to make presentations to parents and the city council.

Issues: Learning to use a range of equipment effectively is a challenge for students and teachers. Moreover, some schools and districts may prefer to steer away from student projects that focus on politically sensitive, real-world topics. A more critical question arises with this type of project, namely, how well does it align with the state and local curriculum standards and assessments for that grade level? In a multidisciplinary learning environment, how can teachers ensure that students acquire the content knowledge and skills they will need to meet state or local performance standards?

Challenge:
aligning multidisciplinary
learning with state standards

Scenario 5

Teams of third-grade students are building computer-controlled model houses and cars. The model houses have lights and a garage door opener that can be controlled using a computer program that the students are writing. The model cars are powered by electric motors and contain devices that sense when the car runs into a wall. The students are writing a computer program that will guide the car through a maze.

Challenge:
determining appropriateness of technology applications and cost effectiveness

Issues: How effective are these types of projects in helping students learn basic reading, writing, and computation skills, as well as other required subject-matter content? Is this a cost-effective way to improve curriculum? Are teachers receiving adequate professional development on such issues as how to assess student work in this environment?

Scenario 6

Students in a tenth-grade social studies class are studying complex systems—for example, a city, a farm, or a rain forest economy. They use computer simulations to "build" objects such as roads, buildings, parks, airports, and power plants and to accomplish such goals as developing a functional economy for their simulated system, managing growth and change, and effectively using resources. The computer simulations are interactive. Students must deal with changing economic situations, natural disasters, and other unforeseen events. The students solve problems individually and collaboratively, exchange advice and opinions, and share their successes and failures.

Challenge:
are technology applications educationally sound?

Issues: What are students actually learning, and how can this learning be assessed? Are the simulations technically and educationally sound? Do the teachers have the knowledge and skills to integrate use of simulations into the curriculum? Does the simulation mislead students by presenting an over simplified view of the phenomenon?

Scenario 7

Each of the students in a high school calculus class has a hand-held calculator/computer on loan from the school. Although the device has the look and feel of a pocket calculator, it has many of the features of a microcomputer. The calculator is specifically designed for use in math and science settings. It can graph functions, solve equations, and carry out a wide range of tasks that students typically learn to do by hand in a calculus course. The course content and assessments are designed around the assumption that the students have routine access to the calculator/computer.

Issues: How well are students learning the underlying concepts that are critical to an understanding of calculus? Has the teacher had appropriate opportunities to learn about instruction and assessment in situations where calculator use is required? How does the use of calculators in this course conform with policies about calculators in students' previous math courses or other math and science courses they will take in the future? What happens if a calculator is lost, stolen, or broken?

Challenge:
assessing students' mastery of underlying concepts; establishing uniform policies of use and assessment

Scenario 8

All teachers in a secondary school use electronic gradebooks. Student records are posted under pseudonyms to ensure confidentiality. Students can monitor their progress, check for missing assignments, and determine how well they are doing relative to the rest of the class. End-of-term reports can be quickly produced and sent electronically to the central office. This electronic gradebook system also makes it easier for teachers to provide students and their parents with individualized written reports at any point during the term.

Issues: Do the teachers have access to the needed hardware and software both at school and at home? Who pays for this hardware and software? Is adequate professional development and technical support available? Is there adequate security built into the system to prevent unauthorized access?

Challenge:
electronic gradebooks: cost, training, and confidentiality

As the scenarios illustrate, information technologies are changing the roles of teachers and students. These technologies have considerable potential to enhance learning. Realizing this potential, however, depends upon working toward successful solutions to many complex issues.

These issues include professional development to educate teachers about how to integrate information technologies into the curriculum and practice, technology-enhanced project-based learning, and authentic assessment using technologies. Realizing technology's potential as an educational tool also depends upon an extended and renewed base of support through school, home, and community connections.

Information Technologies in Education: A Summary of Types, Strengths, and Limitations

The use in schools of information technologies is growing in three overlapping areas: computer and information science, information technology tools, and technology-enhanced learning. A fourth component—telecommunications—ties them all together.

Telecommunications

The telecommunications industry was born in 1844 with the construction of the first commercial telegraph system connecting Baltimore and Washington, D.C. The industry received a big boost with the development of the telephone in 1876 and has grown continually ever since. Recent years have seen the development of communication satellites, fiber optics, cellular telephones, and digital information systems.

Networking provides easy access to vast amounts of information

Computer networking is one of the most significant recent developments in telecommunications. Global computer networks are expanding rapidly in capacity and use. An increasingly important element of global digital telecommunications is the Internet, which is growing daily in users and capabilities. Large collections of reference materials and databases are being digitized and brought online. Through the World Wide Web and the Internet, people can send and receive documents that include text, sound, graphics, audio, and video. The increasingly interactive and graphical capabilities of the World Wide Web are making it possible to establish "virtual" museums, conduct "virtual" field trips, and offer other exciting learning opportunities to students throughout the world.

The totality of information accessible through the Internet can be thought of as a global library, which already dwarfs significantly the libraries in typical high schools. Increasingly, students and teachers have easy access to library materials that used to be available only to scholars living near the great research libraries of the world.

Computer and Information Science

During the past fifty years computer and information science has emerged as a major academic discipline. In addition to computer programming, its major areas of study include databases, networking, human-machine interface, and artificial intelligence (a domain that addresses such problems as voice input to computer, language translation by computer, and expert systems for solving complex problems).

Information science increasingly integrated into K–12 instruction

Many of the basic concepts of computer and information science are now being taught at the K–12 level. Some schools offer elective courses, such as programming in different languages, advanced placement computer science, robotics, and electronics. Other schools integrate instruction about computers into other subjects—for example, integrating computer programming into mathematics courses or infusing electronics into middle school science.

Information Technology Tools

Information technologies are useful and versatile tools that can help people solve problems and accomplish tasks that are central to a variety of academic disciplines. These tools for education can be grouped into the following three categories:

- ***generic tools:*** **These are tools, such as word processors, spreadsheets, database managers, and graphics packages, that can be used in any academic discipline. For example, they include the kinds of tools one finds in an integrated software package like Microsoft Office or ClarisWorks. Once a student has learned how to use these tools, he or she can apply them in almost every area of intellectual work.**

Three basic categories of computer tools

- ***subject-specific tools:*** **These tools are designed for use in a particular academic discipline. Examples are the Musical Instrument Digital Interface (MIDI), which includes hardware and software to help people compose and perform music; Computer-Assisted Design/Manufacturing (CAD/CAM); and graphing calculators.**

- ***constructivist tools:*** **These tools, which require users to acquire some programming skills, are intended to help people learn specific subjects, such as math, music, or science, or to develop their general thinking and learning skills. Examples include most hypermedia authoring systems and all LOGO programming environments.**

Professional development and support needed to modify curriculum

For educators to use these technologies appropriately in the curriculum, they need a substantial amount of professional development and assistance in modifying the curriculum. Because they are introducing innovations into the classroom, they also need the support of school administrators and parents. Educators must be prepared to determine and justify which kinds of skills and processes, such as certain computational algorithms, that students should learn to do by rote. They should determine which they should learn to do with the assistance of simple aids—such as books, pencils, and paper—and which they should learn to do with the assistance of more sophisticated aids—such as calculators, computers, and the Internet.

Technology: changing procedures and methods for managing learning

Information technologies can also be productivity tools for teachers, saving them time and increasing their efficiency. Computers can make it easier for teachers to develop gradebooks, assemble data banks of exam questions, prepare individualized educational plans for students, and write and edit lesson plans and class handouts. Further increases in productivity occur when networks allow teachers to share successful materials easily. An intranet may be used for teacher professional development, lesson plan sharing, and announcements.

Both teachers and students are making wider use of desktop presentation stations, which enable material stored in a computer to be projected onto a screen for the whole class or small groups to view. The system also allows students and teachers to share materials they generate during class. For example, students or teachers in a science class can use a projection system to display analyses of data generated in experiments.

Technology-Enhanced Learning (TEL)

Information technologies can be combined in various ways to assist learners directly with a range of learning tasks. These combinations are called technology-enhanced learning (TEL). Common forms of technology-enhanced learning include the following:

Forms of technology-enhanced learning (TEL)

- *computer-assisted learning (CAL):* CAL systems enable students to do drill and practice, tutorials, and simulations and to work with virtual realities. Most systems also include tools for record keeping and management. CAL—which is sometimes called computer-assisted instruction, computer-based instruction, or various other names—can be used either to supplement traditional instruction or to present entire units or courses of study. An abundance of CAL materials has been developed and is widely available in schools. Many schools find them to be highly motivating to students and an effective aid to learning.

- *distance education*: In distance education, courses or units of study are "delivered" electronically to the school from an outside source. Delivery systems include television or videotape, two-way audio and one-way video, two-way audio and two-way video, and the Internet, including the World Wide Web. A steady rise in the number of distance education courses has expanded the learning opportunities available to students, especially those in remote areas.

- *electronic access to information:* This includes access to information stored on CD-ROMs or available on the Internet. More and more students and teachers are retrieving research information via the Internet, rather than relying on printed books that may be outdated.

- *electronic aids to student and teacher interactivity:* These tools help students and teachers interact electronically with each other and with outside experts, even if the participants are thousands of miles apart. Useful tools include desktop presentation systems, email, and groupware (software designed to help a group of people connected through a computer network to work together on a document or task).

- *Productivity tools with built-in "help" features:* Word processors, spreadsheets, and graphics packages are common forms of productivity software. Today's software includes a variety of features—such as templates, built-in learning aids, and context-sensitive help—that enable users to learn more about an application like word processing at the same time they are using it. The software also contains several features that allow even novices to generate appealing products.

TEL offers several advantages not found in traditional instruction. First, it enables education to occur at a time and place that is convenient for the learner. Convenience is becoming more appreciated, as both formal and informal education providers move to more flexible scheduling and locations. Convenient education also helps learners to assume greater responsibility for their own learning.

Second, TEL can facilitate "just-in-time" education, meaning that students can learn the skills they need right when they need them. With TEL, many skills can be learned in a few minutes, hours, or days—just in time to apply them. Learning times, however, will depend on the backgrounds and capabilities of the learners and on the learning environment. Many recent reforms in education have a goal of teaching students how to learn so they can become lifelong learners. The just-in-time nature of TEL can help to build these learning skills.

Third, TEL fits well with shifts in education that are making it possible for more people to learn in informal settings rather than in formal institutional environments. Almost all home computers come equipped with a CD-ROM drive. Increasingly people are gaining access to the Internet and the World Wide Web from home, library, community, and business locations. As the amount and quality of convenient education materials continue to grow, more and more of the traditional content of formal education will be learned in informal settings. The role of formal education—and of the teacher—will change.

Nevertheless, there are unique advantages to face-to-face interactions between a student and a live human teacher that cannot be replicated with instructional technologies. First, teachers bring irreplaceable dimensions of human understanding to the instructional process. They can read the body language and moods of students and the class. They understand their students as people and know how to interact with them in a manner appropriate to their needs.

Strengths of teacher-student interaction

Second, teachers have pedagogical skills, intelligence, and depths of experience which outweigh those of any machine. The human mind can integrate a lifetime of knowledge into a coherent educational strategy, make judgments informed by a wealth of experience, bring creativity to bear on complex situations, and do countless other intellectual operations that cannot be duplicated by even the best TEL systems.

Third, teachers can be flexible and adaptable in ways that any current computer system cannot. For example, a teacher can facilitate a classroom discussion that ranges across disciplines and can address whatever is on the minds of the students.

Fourth, teachers play a major role in the social development of students. By modeling behaviors, resolving conflicts, or addressing children's social concerns, teachers can help students improve their social skills.

Combining the respective strengths of both human teachers and instructional technologies offers a promising direction for future educational reforms. The role of teachers will shift from what is often described as being the "sage on the stage" to becoming the "guide on the side."

Information Technologies and Standards-Based Reform

As the discussion above has made clear, the growth of instructional technologies is one of the most significant trends shaping education over the past decade; however, it is not the only one. Another major trend, which has emerged during roughly the same period, is the movement to adopt challenging standards for student learning in various subject-matter disciplines. Some of the most critical technology issues for schools relate to how instructional technologies can be integrated effectively with standards-based reform.

Standards-based reform: key components

The standards-based reform movement seeks to raise the academic performance of students in the United States by holding them to higher expectations. Its key components include

- **content standards that specify what students should know and be able to do at particular grade levels in various subjects;**
- **performance standards that define what constitutes adequate and proficient levels of student performance in the areas addressed by content standards;**
- **opportunity-to-learn standards that spell out the kinds of resources and supports that must be in place for students to meet content and performance standards. Among the resources often cited are professional development for teachers, adequate time for learning, access to technology, and intensive, appropriate instruction for students who are falling behind. This concept of opportunity-to-learn is the most controversial component of standards-based reform, and one that many states have chosen not to address right now;**
- **new types of assessment that are better aligned with standards, both in content and format, than traditional standardized multiple-choice tests. For example, many states are designing new assessments that test the specific knowledge and skills addressed in their content standards and that include more open-ended problems, essays, and demonstrations;**
- **professional development standards that specify how to provide opportunities for teachers to engage in continuous, effective learning. These standards serve as a guide to help teachers transform teaching and learning as the content standards require.**

Standards-based reform is well underway at the national, state, and local levels and is exerting a tremendous impact on teaching and learning in classrooms throughout the country. At the national level, various professional organizations have developed voluntary content standards for their disciplines—for example, the standards for mathematics education developed by the National Council of Teachers of Mathematics or the science standards established by the National Research Council.

It is the states, however, that are the major players in standards-based reform. In recent years a majority of states have developed or are in the process of developing content and performance standards and aligned assessments in key subject-matter disciplines. States are using these standards to reshape curriculum and instruction, and many are attaching significant consequences for districts whose students do not meet the standards.

Technology and standards-based reform

Standards-based reform raises two basic sets of issues for schools and teachers implementing instructional technologies. The first set of issues revolves around standards for technology literacy as a goal in itself. What should students know and be able to do to become technologically literate? The second set of issues pertains to the effective incorporation of technology into standards in other subject-matter disciplines. Which technological tools, for example, should a student be able to use proficiently as part of the study of science? How can technology-enhanced learning help students meet science performance standards?

National Educational Technology Standards

In 1996 the National Council for the Accreditation of Teacher Education (NCATE) adopted guidelines developed by the International Society for Technology in Education (ISTE) for use in the accreditation of pre-service education programs. In addition to technology foundation standards that pertain to all teachers, curriculum standards were developed for educational computing and technology literacy, secondary computer science education, and advanced study in educational computing and technology leadership.

NET standards for students

Two years later ISTE published technology foundation standards for students developed by a national consortium of educational organizations, including the National Foundation for the Improvement of Education. These standards—the National Educational Technology Standards (NETS)—describe what students should know and be able to do in order to live, learn, and work successfully in a complex, information-rich society.

Examples of specific NETS competencies

As a logical expansion of the NETS project, the consortium worked with the subject matter societies (NCTE, NCTM, etc.) to write *NETS for Students: Connecting Curriculum and Technology* (ISTE 1999). This document provides examples that connect subject matter standards and technology standards. The consortium's next project is the development of teacher preparation standards. Subsequently, the consortium will develop standards for the kinds of educational supports (such as access, professional development, and support services) that are essential for effective uses of technology and standards for student assessment and evaluation in technology use.

Categories of NETS

The technology foundation standards for students address six broad categories of knowledge and skills. These categories are

- **understanding of basic technology operations and concepts;**
- **understanding of the social, ethical, and human issues related to technology, including responsible technology use;**
- **use of technology productivity tools;**
- **use of technology communication tools;**
- **use of technology research tools;**
- **use of technology tools to solve problems and make decisions.**

To give educators a fuller picture of the kinds of skills envisioned by the foundation standards, the NETS project has also developed profiles describing the technology competencies that students should exhibit prior to completing grades PreK–2, 3–5, 6–8, and 9–12. Consider, for example, some of the NETS competencies related to the fourth technology foundation standard (use of technology communication tools).

Examples of specific NETS competencies

- **By the end of grade two, students should be able to gather information and communicate with others using telecommunications with support from teachers, family members, or student partners.**

- **By the end of grade five, students should be able to use telecommunications and online resources to participate in collaborative problem-solving activities for the purpose of developing solutions or products for audiences inside and outside the classroom.**

- **By the end of grade eight, students should be able to collaborate with peers, experts, and others using telecommunications and collaborative tools to investigate curriculum-related problems, issues, and information and to develop solutions or products for audiences inside and outside the classroom.**

- **By the end of grade twelve, students should be able to collaborate with peers, experts, and others to contribute to a content-related knowledge base by using technology to compile, synthesize, produce, and disseminate information, models, and other creative works.**

Along with these grade-level profiles, the NETS project has published scenarios of classroom practices that facilitate learning in the foundation competencies. To advance students' competencies in using technology for communications, for example, a grade eight teacher in one scenario asks students to research rocks and minerals on a CD-ROM encyclopedia, communicate with geologists via email, and create hypermedia presentations about what they learned to share with their class.

Using Technology to Meet Standards in Other Disciplines

Used appropriately, technology can help students learn the concepts and master the processes embodied in the content standards for a variety of disciplines. Technology can make dry concepts come to life and can be a strong motivator for disengaged students. Indeed, technology can be a powerful impetus for reforming teaching and learning along the lines envisioned in various national and state standards.

Technology standards as support to acquire additional competencies

Many current standards emphasize the need for students to develop higher-order thinking and problem-solving skills—competencies that can be enhanced through such projects as collecting and analyzing real-time data using a computer or designing and conducting investigations of authentic problems. The ability to communicate what one learns with clarity and precision is another skill embodied in various content standards—one that students can hone using word processing, telecommunications, and presentation tools.

Recognizing this potential, many of the standards development committees have incorporated technology into content standards for various disciplines. For example, technology is one of the guiding principles of the 1998 draft mathematics standards developed by the National Council of Teachers of Mathematics to update their 1989 standards. This principle calls upon mathematics instructional programs to use technology to help all students understand mathematics and prepare them to use mathematics in an increasingly technological world. Numerous other references to technology are woven throughout the mathematics standards.

Success of technology applications for education dependent upon adequate supports

The NCTM standards also explicitly recognize the value of technology tools in helping students learn important mathematical content and processes. To foster the development of number and operation sense, for example, the standards suggest that all students should use calculators at appropriate times as computational tools, particularly when many or cumbersome computations are necessary to solve problems. They further recommend that calculators be set aside when the focus of instruction is to develop student-generated or conventional computational algorithms. Similarly, the math standards note that computer modeling software allows students to develop and explore models of complex situations once reserved for advanced courses. Teachers are also advised to ensure that students understand the relationships being modeled.

How well information technologies are used will depend on the adequacy of the supports available. Teachers must be well prepared to make informed judgments about when and how to use these tools. Districts and schools must provide professional development; curriculum development; changes in assessment systems; adequate funding for hardware, software, and technical support; and education designed to help parents and other community members learn about computer technology in education. Several of these issues are discussed more fully in other papers in this series.

"Information Technologies in Education: A Survey of Uses and Issues" is one of several papers included in *Connecting the Bits, A reference for using technology in teaching and learning in K–12 schools*, issued by the National Foundation for the Improvement of Education in 2000, and available at www.nfie.org.

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U.S. Department of Commerce National Telecommunications and Information Administration. 2000. Falling through the net: Defining the digital divide. Washington, D.C. http//www.ntia.doc.gov/ntiahome/digitaldivide/.

This report surveys household access to telephones, computers, and the Internet, updating the surveys in two previous reports. It also provides significant new information on individual Internet usage, including how people connect to the Internet and spend their time online. Finally it reports the challenges ahead in solving the digital divide and highlights the significance of several key policies in promoting access.

U.S. Department of Education National Center for Education Statistics. 1999. *Internet access in public schools and classrooms: 1994-1998* (NCES 99-017). Washington, D.C.: Government Printing Office. http://nces.ed.gov/pubs99/199017.html.

A statistical report of access to the Internet in schools and classrooms throughout the United States.

Project-Based Learning and Information Technologies

Introduction

Most teachers, at one time or another, give open-ended assignments that allow students some choice over topic and extend over a considerable period of time. Often these assignments call upon students to exercise a broad range of knowledge and skills from various academic and vocational disciplines. Students design, carry out, and report on their own investigations, either alone or in collaboration with others. These kinds of activities are sometimes called project-based learning.

Information technologies can increase the versatility and value of project-based learning. For example, technology makes it possible for individuals and teams to carry out in-depth projects that draw on various media and information resources from throughout the world.

This paper discusses

- project-based learning that makes effective use of information technologies;
- the research foundations and benefits of project-based learning;
- project-based learning in the classroom, including instructional goals, implementation, and student assessment;
- project-based learning, information technologies, and hardware and software;
- professional development needs for implementing technology-enhanced project-based learning;
- an annotated bibliography.

Project-Based Learning that Makes Effective Use of Information Technologies: An Example and Key Characteristics

A Project-Based Learning Example: "Does Cincinnati Need Another Bridge?"

Students of all ages have the knowledge, skills, and interest to work on "authentic" learning tasks—those that involve substantive, real-world problems. Projects into which technology is integrated often involve authentic work. Consider the following example:

Project-based learning: a summary of an example

When Cincinnati proposed building a new bridge across the Ohio River, teachers and students at Southgate Public Elementary School in nearby Kentucky decided to study the situation. They began by conducting a community survey and then tabulated the results in an electronic spreadsheet. They conducted background research on the history of bridges and the city. Using a computer-based geometry simulation, they reviewed the geometry of bridges and created models of historical bridges. They visited existing bridges and used video cameras to monitor rush-hour traffic. From this video record, they compiled precise statistics on the number and speed of people and vehicles. They then used these statistics to create multimedia simulations of hypothetical new bridge designs.

The Southgate students tested their ideas of bridge geometry by using straws to construct actual model bridges, and they compared the load-bearing capacities of the different models. The students revisited some of Cincinnati's bridges, this time with an architect, to ask questions not answered by their research. Finally, they submitted a report to the city of Cincinnati (Salisbury 1995).

Key Characteristics of Project-Based Learning

The Cincinnati bridge study illustrates many of the following key characteristics of project-based learning:

Key characteristics

- ***Students have some choice*** **of topic and some control over the content of the project and the extent of their investigations. Students can shape their project to fit their own interests and abilities. For instance, the Cincinnati bridge project included activities for music and art as well as geometry and physical science.**

- *The teacher acts as a facilitator,* designing activities and providing resources and advice to students as they pursue their investigations. It is the students, however, who collect and analyze the information, make discoveries, and report their results.

- *The context for the subject matter is larger than the immediate lesson.* The bridge across the Ohio River was a community issue being discussed in the media. It was of actual concern to students' families.

- *Students conduct research* using multiple sources of information, such as books, online databases, videotapes, interviews (which they can conduct in person or via telecommunications), and their own experiments. Even if their projects are based on the same topic, different students may use considerably different sources of information.

- *The project usually cuts across multiple disciplines.* Students are expected to draw upon a broad range of knowledge and skills and to "stretch" their own ranges. Initially the bridge project was a study of geometric shapes, but it expanded to incorporate statistics, charting, social studies, physics, language arts, and technology.

- *The project extends over a significant period of time,* usually from several class periods to an entire school year. (The Southgate students studied the Cincinnati bridges for six weeks.) Projects enable students to practice the skills they need to become self-disciplined learners. Students plan how to use their time effectively and share resources such as computers, digital cameras, camcorders, and computer network access. One goal of project-based learning is for students to become better managers of their time and other resources.

- *Students design and develop a product, presentation, or performance* that can be used or viewed by others. In the simplest form, students may present the results of their projects in class as reports or posters. Other projects may extend student products beyond the school boundaries in the form of broadcasts, publications, and public events. Students may create products of significant and lasting value, such as environmental assessments or permanent information displays. The primary audience for the Southgate project report was the city of Cincinnati.

- ***A team of people may work on the project.*** **The team may consist of an entire class, several classes, or even several remote sites. In these cases, individuals or small groups work on different components of a large task, and their joint efforts are often coordinated through technology. The Southgate project involved fourth, fifth, and sixth graders, who recorded their investigations on shared central computer databases. Multisite projects often rely on email or videoconferencing to share information and findings.**

- ***The project has several instructional goals.*** **In addition, students may achieve other unforeseen goals as they explore complex topics from a variety of perspectives.**

Research Foundations and Benefits of Project-Based Learning

A Summary of Research on Project-Based Learning

Project-based learning is a versatile approach to instruction that can readily be used in conjunction with other approaches. Teachers who make extensive use of project-based learning are blending a number of educational ideas, each supported by substantial research. Summarized below are some of the main areas of educational research that underlie project-based learning.

Constructivism is an educational theory of learning premised on the idea that students create, or "construct," their own knowledge in the context of their own experiences.

Students learn better when they are "doing"

Constructivism holds that students learn better when they are actively engaged in "doing," rather than passively engaged in "receiving" knowledge. Project-based learning is one way to create rich learning environments that invite students to construct personal knowledge.

Howard Gardner and David Perkins are co-directors of *Project Zero* at Harvard University, a large and longstanding research project that studies ways to improve content, pedagogy, and assessment in education.

Gardner's theory of *multiple intelligences*, which he first put forward in 1983, emphasizes the need for personalization of schooling (Gardner 1995). Gardner argues that each person has several different types of intelligence, such as musical intelligence, linguistic intelligence, and logical-mathematical intelligence. Through appropriate education and experience, these various intelligences can be enhanced—a person can develop his or her own individual potential. Gardner strongly supports the use of project-based learning as one approach to create a learning environment that enhances each student's multiple intelligences.

David Perkins's 1992 book, *Smart Schools*, analyzes a number of different educational theories and approaches to education in a way that strongly supports Gardner's theory of multiple intelligences. Perkins's book contains extensive research-based evidence that education can be considerably improved by focusing on higher-order cognitive skills using project-based learning and encouraging more explicit and appropriate teaching for transfer. In other words, student learning is enhanced when students recognize patterns and rules in one situation that they can apply to other, seemingly dissimilar situations.

Students generate and test their own hypotheses

Inquiry-based learning, or discovery-based learning, often calls on students to generate and test their own hypotheses. The emphasis may be on discovering specific facts or on developing a higher-order understanding of the topic and ideas being explored. Students are encouraged to develop curiosity as a habit and to approach all learning with a disposition toward questioning and systematic investigation. Project-based learning often makes use of inquiry-based teaching methods. Research indicates that hands-on, inquiry-based instruction is generally more effective than traditional didactic presentation in improving students' problem-solving abilities in particular subject domains (Helgeson 1992).

A recent large-scale analysis of data from the National Assessment of Educational Progress looked at the effects of using computers in mathematics instruction and found that technology could make a difference, but it depended upon how it was used (Wenglinsky 1998). This study found that for eighth graders, the use of computers to teach higher-order thinking skills was associated with a one-third of a grade-level increase in mathematics achievement; for fourth graders the contribution was about one-tenth of a grade-level improvement.

Students collaborate to complete a project

Cooperative learning and collaborative problem solving frequently engage teams of students as they work to complete a project. Cooperative learning has been shown to be effective in improving academic and social skills; however, successful cooperative learning requires teachers to organize carefully and, in some cases, to give students explicit training in collaboration and communication (Johnson 1986; Johnson and Johnson 1989). Project-based learning provides an authentic environment in which students can become more skillful at learning and solving problems through collaboration.

Similarities between project-based learning and process writing

Process writing finds a parallel in project-based learning. Many teachers are familiar with presenting writing as a process and are aware that the steps of process writing—brainstorming, organizing ideas, developing a draft, obtaining feedback, revising, and publishing—are similar to those required in many other creative projects. Often reports or computer-aided presentations created through process writing constitute a project's final product.

Additional support for project-based learning can be found in the various reports on student content standards developed by organizations such as the National Academy of Sciences and the National Council of Teachers of Mathematics. These reports stress the importance of engaging students in authentic and multidisciplinary tasks, which are hallmarks of many project-based learning environments.

Benefits of Project-Based Learning

A search of the literature identifies thousands of articles on classroom projects. Most of these reports can be considered testimonials, in which teachers tell how they use projects in their teaching and how successful they feel it has been. Benefits attributed to project-based learning include:

Teacher-reported benefits of project-based learning

- ***increased motivation*: Accounts of projects often report that students willingly devote extra time or effort to the project or that previously hard-to-reach students begin to participate in class. Teachers often report improvements in attendance and decreases in tardiness. Students often report that projects are more fun and more engaging than other components of the curriculum.**

- *increased problem-solving ability*: Research on how to improve students' higher-order cognitive skills emphasizes the need for students to engage in problem-solving tasks and for teachers to provide specific instruction on how to attack and solve problems (Moursund 1995; Perkins 1992). Many articles describe project-based learning environments, in which students actively and successfully pose and solve complex problems.

- *improved research skills*: Most projects require students to move beyond easily available printed information sources such as textbooks, encyclopedias, and dictionaries. Information technologies offer ready access to excellent additional sources of information on computer disk, CD-ROM, and the Internet. Project-based learning also encourages students to become independent researchers, which is in keeping with the American Library Association's call for "information literacy" as a fundamental goal. The ALA defines information literacy as the abilities to recognize a need for information, to identify and find the needed information, to evaluate and organize the information, and to use it effectively to address the problem or issue at hand (Breivik and Senn 1994). Project-based learning can provide an authentic context that motivates students to increase their levels of information literacy.

- *increased collaboration*: Many projects entail group work, which requires students to develop and practice communication skills (Johnson and Johnson 1989). Through collaborative projects, students gain experience in teaching their peers, evaluating the work of others, sharing information online, and learning cooperatively. Current cognitive theories suggest that learning is a social phenomenon and that students will learn more in a collaborative environment (Wiburg 1994).

- *increased resource-management skills*: Part of becoming an independent learner is taking responsibility for completing complex tasks. Well-implemented project-based learning gives students instruction and practice in organizing projects and in allocating time, equipment, and other resources to complete tasks on schedule.

Project-Based Learning in the Classroom: Instructional Goals, Implementation, and Student Assessment

Instructional Goals and Design of Projects

Project design:
set clear academic goals

The design of a learning project begins with the formulation of clear academic goals. Some of these will be specific to the subjects under study—understanding the structural strength of geometric shapes, the history of the Civil Rights movement, or the effects of mass and acceleration on moving bodies. Another set of goals has to do with the process of learning—acquiring the knowledge, skills, and abilities to pursue complex tasks over time; work in a team; or locate, retrieve, organize, and apply information gleaned from multiple sources.

Once the learning goals are established, teachers (or teachers and students working together) can begin to design and schedule activities. One time-tested set of project planning guidelines, developed by Al Rogers of the Global SchoolNet Foundation, comes out of educational telecommunications, where teachers have been developing multisite projects for many years (Rogers et al. 1990).

Among other characteristics, successful projects

- **have specific goals, tasks, and outcomes aligned with instructional objectives;**
- **have specific beginning and ending dates and intermediate deadlines;**
- **provide examples of the kinds of writing or data collection that students will submit.**

Teachers and students need to carefully inventory and allocate resources—time, prerequisite knowledge and skills, technology, and information sources. This is particularly true when activities depend on sophisticated or scarce technology or on collaboration with other classrooms or subject-matter experts from the community. Written or unwritten rules governing the project may limit the kinds of resources that students may use. For example, there may be rules on how much help is allowed from parents and others.

As the student or team begins to understand the demands of the project and determines the resources that are available, the next step is to develop a plan of action. What tasks need to be accomplished? What resources are needed to accomplish these tasks? Can some of the tasks be done simultaneously? Which must be completed before others can be started? In a large project, it is helpful to have milestones—specific tasks to be completed by specific times. What are the criteria to be used to measure whether a milestone has been successfully reached?

Project design:
develop a plan of action

A project should be carefully crafted from the beginning to specify its learning goals and expected outcomes, the resources available as well as the resource limitations, and a plan of action. These activities take place simultaneously, cyclically, and repeatedly throughout a project. The process of working on any one of these steps produces information and insights that may lead one to rethink another step.

Project design:
allow for contingencies

A common pitfall for both teachers and students is failing to allocate enough resources (especially time) to provide for unforeseen difficulties. What happens if a team member is ill? What happens if a particular task proves to be more difficult than anticipated? What happens if a needed piece of equipment is out for repair? A robust plan includes a "contingency fund" allocation of time and other resources.

It may be useful for the teacher to summarize project planning in a table, much like that below, which lays out the tasks and subtasks, resources needed, timelines for undertaking each job, and milestones that indicate the task's completion:

	Description	Resources	Timeline	Milestones
Task 1				
Subtask 1.1				
Subtask 1.2				
Task 2, etc.				

A similar table can be provided to students as a prompt and guide for doing their own planning.

Feedback and Assessment

Conventional instruction often calls upon students to carry out relatively small tasks (textbook exercises, short essays, quizzes) and then to receive answers, feedback, and a grade from the teacher. As noted above, project-based learning often involves real-world, authentic activities that may be partially guided by an individual's strengths and interests.

Project design: establish appropriate evaluation of student work

As a result, not all of the students involved in a project are learning the same things at the same time. This can make the teacher's task of assessing student progress and providing feedback more complex than it is in other forms of instruction.

Characteristics of authentic assessment

Methods of *authentic assessment* are well suited to the evaluation of such projects. Authentic assessment requires students to apply and demonstrate their knowledge by carrying out real-world tasks and creating actual products. Examples include retrieving information from multiple sources and integrating it into well-reasoned arguments to support an idea; creating a work of art or music to enhance a presentation; and designing and carrying out an experiment to test a hypothesis.

Authentic assessment involves a careful examination of student products and performances. Increasingly, teachers are helping students learn to critique their own and one another's work.

For instance, Vito Dipinto and Sandra Turner (1995) describe a three-part procedure in which seventh-grade students are taught how to evaluate their own hypermedia reports. Each student researches a mammal as part of the science curriculum and presents his or her findings in the form of a HyperCard stack.

The teacher first models how to use an evaluation rubric and what to look for in a successful product. A few students volunteer to have their stacks evaluated, and the class clusters around a single machine while the teacher critiques a stack. Evaluation includes the extent and accuracy of its information, the mechanics of the writing, and the design of the presentation.

Students then evaluate one another's work using a peer assessment feedback form. Finally, students write a short essay, guided by a set of questions, in which they reflect on what and how they learned during the project. The teacher's modeling, the assessment feedback form, and the discussion about the evaluation rubric provide the necessary scaffolding for students to complete their assessment tasks successfully.

A number of states and individual school districts now use portfolio assessment, in which the output of projects and other student work becomes part of an individual's record. Technology has helped to facilitate the storage and evaluation of student products.

Technology-assisted authentic assessment

Moersch and Fisher (1995) describe a computer application they designed to help both the teacher and the student showcase examples of student work. The software contains scoring rubrics in which the teacher can check off skills and levels of mastery. The multimedia features of the computer are used to capture digital information (text, sound, graphics, video) that represents student work from both non-computer projects and computer-based activities.

Authentic assessment is an important component of the continuing search for evaluation methods that are valid, reliable, and fair (Baker 1993) and that move the curriculum and pedagogy in directions that will improve education.

Robert Rothman's 1995 book, *Measuring Up*, discusses pros and cons of authentic assessment, summarizes the research literature, and gives a number of examples of major implementation efforts. Assessment is addressed in more detail in another report in this series.

Information Technologies, Hardware and Software: Their Use in Project-Based Learning

Information Technologies in Project-Based Learning

Projects are commonplace in formal technology classes, in which students develop computer programs, databases, multimedia, or other products on the way to mastering the equipment and software. However, information technologies can also facilitate project-based learning in science, language arts, fine arts, social studies, and other subject-matter disciplines.

For example:

Project-based learning in specific academic disciplines

- **A class of third graders is studying the modern Civil Rights movement in the United States. One pair of girls uses multimedia authoring software to create a simulated TV newscast from Montgomery, Alabama, on the day Martin Luther King Jr. is released from jail in Birmingham. In preparing the "newscast," they study King's speeches, develop a story board, and write, edit, rehearse, and perform their scripts. The authoring software allows them to include a video clip of the actual speech King gave that day in 1963. Other students in the same class approach the problem in a different manner. They use desktop publishing software to produce a simulated *Montgomery Advertiser* for December 2, 1955, the morning after the arrest of Rosa Parks that triggered a major bus boycott (Nix 1995).**

- **Sixth graders with learning disabilities use the KIDLINK list server to collect sunrise/sunset observations from around the world—almost pole to pole—on the day of the winter solstice. Although the students are in Wisconsin, they receive regular assistance from a professional meteorologist in Maryland via the World Wide Web. Students communicate with participating sites by email, locate sites by latitude and longitude, compute daylight hours, and create a database of sites and daylight. Following the data collection and analysis, students study the implications of their findings, such as the scientific explanation for why we have seasons. They pose questions and seek answers on such topics as the effects of living in constant daylight or darkness for part of the year (SIG/Tel 1995).**

- **Students at several elementary and secondary schools in Idaho use CD-ROMs, video and audio production gear, power tools, and robots to carry out a variety of assignments, from publishing a class newsletter to building a model car that can protect a raw egg in a high-speed collision. One instructional goal of these projects is to help students understand the importance of letting the problems dictate which kind of equipment to use. Students work together in small teams. The teacher is available to offer suggestions and explain how the equipment works, but avoids prescribing solutions (Graumann 1993).**

- **Nebraska high school students "shadow" adults on the job. The students employ a variety of information technologies to take notes, make recordings, and take pictures. Using hypermedia they incorporate these materials into multimedia research reports on careers. The nine-week project begins with students learning interviewing techniques and computer-based approaches to business communications (Hoffman 1995).**

- **A three-period course in an Oregon high school integrates the subjects of United States history and literature with information technology. The coursework involves the creation of both group and individual hypermedia projects that integrate knowledge from the three areas. Teams of students work together to study the Great Depression in the United States, dividing the research into such areas as transportation, family life, clothing, music, and food. The students make use of a wide range of information resources and information technology tools. They learn from one another and help their teachers learn. They present their finished products to the entire class (Smith 1993).**

As these examples show, information technologies can affect both the nature and content of project-based learning. In some cases, technology makes it easier to do basic tasks, as when students use a word processor to revise text during the writing process.

In other cases, technology extends the scope of a project in ways that would otherwise be impossible, as when students gather simultaneous data from remote sites via telecommunications, or publish their results in the form of videotape or a World Wide Web page.

Hardware and Software Considerations

Technology-dependent projects require hardware and software that are readily available and properly configured. In addition, both teachers and students must have sufficient knowledge and skills to take advantage of these tools. Project planners must allot time for this basic training or must select activities that help participants acquire new technology skills as the project proceeds. If teachers expect to spend part of a project teaching information technology skills, they may need to limit the scope of other content.

Teachers sometimes feel that they cannot use information technologies in project-based learning because their schools or classrooms lack appropriate modern equipment, but many teachers have overcome these difficulties.

Non-computer-based technology in the classroom

Projects can often be designed for a one-computer classroom. Multimedia writer Fred D'Ignazio has pointed out that many technology tools are already available in schools (D'Ignazio 1995-1996). Camcorders, still cameras, VCRs, television sets, and tape recorders can often be borrowed or obtained as gifts. These devices can support multimedia project-based activities that do not require computers.

These common tools are often familiar to teachers and students from home use and may require little initial training. Photos and recordings made on these simple tools can later be incorporated or edited into computer-based multimedia presentations by adding such devices as digitizing adapters and scanners. Digital versions of cameras and recorders can provide direct input to computer applications.

Numerous specialized computer products can also support project-based learning. Hand-held digital appliances can help students perform specialized data collection and analysis tasks for a project, especially when a field-based location is involved. Multimedia authoring programs, available for most computer platforms, allow teachers and students to develop complex and visually attractive computer presentations and databases even if they do not have advanced programming skills.

With just a brief introduction to the software, students can undertake projects that are both challenging and intrinsically rewarding. When they want to use the more advanced features of the software, they can learn on their own, from fellow students, or with a modest amount of help from the teacher.

Ease of software use in the classroom

Electronic information-gathering tools have become more accessible in recent years. Searching for Internet-based information formerly required mastery of arcane file transfer commands. The World Wide Web has made this activity technically easy in classrooms that enjoy Internet access.

CD-ROM drives, which typically used to be housed at special workstations in the library, are standard equipment on computers. The World Wide Web and CD-ROM technologies allow students to find original source material from the past and present—the latest photographs from the Hubble Space Telescope, original drafts of the Gettysburg Address in Lincoln's handwriting, current research reports, and audio clips of T. S. Eliot reading his own poetry aloud.

The primary challenge for teachers in technology-based projects is not to acquire more information. Instead, the challenge lies in applying their training and wisdom to help students search through, organize, and make sense of the vast amount of information already available. An important aspect of this challenge centers on helping students focus on the subjects they are learning rather than on the bells and whistles of the technology.

Teachers' challenge: applying their wisdom to help students locate and analyze information

Professional Development Needs for Implementing Technologically Enhanced Project-Based Learning

Some teachers remain uncomfortable with having their students work with sophisticated technology in multidisciplinary projects that extend beyond the teacher's area of expertise. They feel they need additional professional development to take such a step.

The lack of adequate professional development has been described as possibly the single greatest obstacle to teachers making use of educational technology (Office of Technology Assessment 1995).

Some professional development challenges include

- **learning how to help students function productively in a project-based learning environment;**
- **learning more about how to find or develop good projects that fit one's instructional objectives and the available equipment resources;**
- **learning how to provide effective feedback to students, both as they work on projects and after they complete them;**
- **learning how to work with students in a "high-tech" project-based learning environment in which many of the students know more about the technology than the teacher does.**

Professional development needs in order to apply technology for classroom uses

These changes require commitment from teachers and support from the school over a period of time. Means and Olson (1995) found that even after extensive professional development, many teachers continue to use traditional didactic forms of instruction, primarily because they are reluctant to add to the multiple demands they already shoulder. Breivik and Senn (1994) reported that for many of their correspondents, the transition from expository to resource-based learning took from three to five years.

There has been a great deal of research on professional development and its role as a change agent in education. It is one of the major keys to school renewal and school improvement.

Transition to resource-based learning: three to five years

Another paper in this report focuses specifically on professional development for information technologies in education. Perhaps the single most relevant idea for this discussion is that a new paradigm is taking shape in which teachers view themselves as lifelong learners.

Final Remarks

Project-based learning is a well-established component of our educational system. It is an excellent vehicle for helping students learn to carry out authentic, multidisciplinary tasks in which they budget their time, make effective use of limited resources, and work with other people.

Information technologies bring new opportunities and challenges to project-based learning. There is a constant expansion of computer facilities and connectivity in schools.

In addition, many schools and school districts are placing considerable emphasis on technology-oriented professional development. This combination of improving facilities and increasing teacher knowledge supports the wider use of information technologies in project-based learning.

"Project-Based Learning and Information Technologies" is one of several papers included in *Connecting the Bits, A reference for using technology in teaching and learning in K–12 schools*, issued by the National Foundation for the Improvement of Education in 2000, and available at www.nfie.org.

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Assessment and Information Technologies in the K–12 Curriculum

Introduction

The growth of information technologies offers and, in some cases, necessitates new means of assessing student learning. Information technology has the capacity not only to make existing modes of assessment more efficient, but also to assess skills and processes not easily measurable by other means. These advantages are made possible by such tools as computer-adaptive testing, electronic portfolios, computer banks of examination questions, video presentations, computer simulations, and computer-based networking.

Information technologies also make it possible to bring assessment more in line with instructional practices that emphasize real-world tasks, deep understanding, problem solving, and collaboration with others. Some of the most innovative forms of technology-based assessment can be woven into everyday teaching and learning so that students are not even aware they are being assessed.

Just because technology-based assessments are different from traditional testing methods, however, does not mean that they are inherently better. As with any type of assessment, their quality will depend on how well they measure what they are supposed to measure, whether they produce consistent results, and whether they are fair and reasonably cost-effective.

Assessment with information technologies also places new demands on teachers. They must learn how to implement these new approaches, weave them into their daily instruction, and interpret the information yielded. Successful implementation of technology-based assessment requires additional research and development, professional development for teachers and other stakeholders, and compatible changes in curriculum and instruction.

This paper

- reviews the purposes and principles of assessment, the varying stakes attached, and some hallmarks of good assessment design;
- outlines new trends in assessment;
- discusses technology's effect on instruction and assessment;
- describes a range of technology-based assessment tools and processes;
- summarizes how technology can add to assessment;
- raises issues in designing and implementing technology-based assessments;
- includes an annotated bibliography.

Purposes and Principles of Assessment

Assessment fulfills several purposes in an educational system. Among the most common are the following (OTA 1992):

Purposes for assessment in educational systems

- **to provide feedback to teachers, students, and parents on the effects of instruction, which can be used to improve teaching and learning;**
- **to provide information that can be used to select, sort, place, or credential students;**
- **to monitor the performance of programs, schools, or school systems and to hold educators accountable for students' learning.**

There are many kinds of assessments that measure student achievement, and each is designed for different purposes. Some assessments are intended mainly for use within the classroom. Others are intended to provide information to external audiences, such as parents, policy makers, and funding agents. An assessment developed by a teacher to determine what students have learned after studying World War I may be quite a bit different from one designed to assess whether a student has learned history sufficiently to graduate from high school. Some purposes, such as making decisions about college admissions, require assessments that yield individual scores, while others, such as determining how well students in various school districts are achieving in mathematics, can be based on aggregated group scores.

Low-stakes assessment

While assessments are meant to motivate people to perform well, the degree of motivation often depends on the stakes, or consequences, attached to their use. At one end of the spectrum are informal kinds of assessment with low stakes. Assume, for example, that a student is writing a paper using a word processor. The student reads what she has written and notes that a sentence does not communicate the idea she has in mind. She changes the sentence. She runs the spell checker (an electronic aid to self-assessment) and corrects a couple of keyboarding or spelling errors. The student then shares her paper with several fellow students, all of whom have received instruction and practice in peer assessment. The students make use of a set of formal criteria (a rubric) that guides their feedback in such areas as how well the document communicates, how well it holds the interest of the reader, and what unique and exciting features it offers the reader.

Moderate-stakes assessment

The stakes rise somewhat as a teacher wanders purposefully around the classroom, watching students work in groups to accomplish a task. The teacher makes mental and written notes (perhaps using a handheld personal digital assistant) about activities of individuals and groups. The teacher observes that a group is doing well at following the directions and tells the students so. The teacher may make a suggestion that will help the group do even better and then share this suggestion with the whole class.

The stakes become higher on major projects that engage students over a period of weeks. A significant portion of a student's grade may depend on producing a desktop-published newsletter that is carefully researched, designed, written, and produced. As the project proceeds, students receive feedback on drafts from their peers and their teacher and reflect upon how to make their drafts better. Much of the grade on the project may be based on the final results and may take into consideration peer assessment, teacher assessment, and, perhaps, assessment from an outside expert.

High-stakes assessment

Assessments with very high stakes are intended to be highly motivating to students, teachers, school administrators, or others. College entrance exams, for example, hold important consequences for individuals; in fact, a whole industry has grown up to develop test-specific software and other materials that students can use to try to boost their scores. Examples of assessments with high stakes for teachers and administrators are state standards-based assessments, which parents, the public, and policy makers may use to make judgments about the quality of education in schools and districts. It is often said that assessment drives instruction; when stakes are high, teachers may be motivated to "teach to the test."

Producing formal assessments that accurately measure performance is a complex venture. Whatever their intended use, assessments should be used only for those purposes for which they have been designed. This is a fundamental principle of measurement science.

The following basic principles are commonly used to guide good test design. While these principles are important for all types of tests, the relative importance of each will vary, depending on how the test will be used.

Principles of good test design

- **The test should be valid. It should measure what it is designed to measure, so that a high score correlates with a high level of knowledge and skill in the subject being tested.**
- **The test should be reliable, so that it yields consistent results when given repeatedly under similar conditions. To be considered reliable, a test should also have "generalizability." In other words, the items on the test should provide a good sample of the broader domain of knowledge and skills being tested, and a test taker's performance should indicate how well he understands that broader domain.**
- **The test should be fair. It should not give an advantage to particular racial, socioeconomic, or gender groups.**
- **The test should have a "reasonable" cost in terms of the materials and labor needed to design, administer, and score it. Costs also include the student time and expense required to prepare for and take the test.**

Where improvement in assessment is needed

Professional test developers have devoted considerable research to these principles, yet many classroom practitioners and others feel that conventional, multiple-choice standardized tests do not adequately assess the range of knowledge and skills that students should be learning. Moreover, many argue, conventional tests sometimes drive instruction in counterproductive directions by focusing on a narrow range of the curriculum and certain kinds of low-level skills.

Much of the recent history of educational testing involves a search for new forms of assessment that will incorporate basic principles of measurement while also encouraging effective instructional practices and giving a fuller picture of students' understanding. This need for a better match between instruction and assessment is particularly apparent in classrooms that use technology-enhanced learning, which often has different goals and includes different instructional experiences than the kinds of instruction rewarded by traditional tests.

Trends in Assessment

The past decade has seen enormous change in the field of assessment. One notable trend is the rising interest in authentic assessment, which requires students to solve problems and accomplish tasks similar to those found in complex, real-world situations—hence the term "authentic." Unlike conventional test formats, which usually ask students to choose from among multiple answers already provided, authentic assessments involve "open-ended" test questions that call upon students to construct their own responses.

Performance assessments

A common type of authentic assessment is performance assessment, whereby students demonstrate their knowledge and skills by creating an answer or product, such as writing an essay, giving an oral presentation, generating a model on the computer, or performing an experiment. Often these kinds of assessments seek to measure students' masteries of higher-order cognitive skills; some may also assess their abilities to work in groups. Authentic assessments often draw upon the abilities of students to assess both themselves and their peers. These kinds of assessments place greater demands on educators, who must be prepared to judge them according to specified rubrics.

Linking assessment to content standards

A second major trend is the movement to link assessment to challenging content standards for what students should know and be able to do in various subject matter disciplines at particular grade levels. Many states have established or are in the process of establishing these kinds of content standards, along with performance standards that define various levels of student mastery of the content standards. To measure whether students are making adequate progress, states and districts are also developing new assessment systems aligned with their content standards. Many of these new assessments include some type of authentic assessment.

Standards-based assessment brings new dimensions to the assessment process by compelling states to make critical decisions about what to test, how to test, and where to set cut scores for various levels of achievement (Green 1995). In such assessments, content standards directly prescribe what items are included in the testing. These assessments may provide the first experience for educators and students in which the content standards become explicit and concrete (Robinson 1998).

Several states have attached important consequences to the results of these new assessments, such as using them to determine whether students will graduate or pass to the next grade or to judge whether schools will be placed on "probation" for low performance. In a sense, one goal of the standards movement is to build assessments that represent what students should know and be able to do, so that teaching to the test becomes teaching the curriculum (Green 1995). As more states adopt technology standards, they will begin to add technology to the assessment skills and knowledge required for high school graduation.

Technology's Effect on Instruction and Assessment:

A Changing Vision

At the same time this changing vision of assessment is taking shape, rapid advancements are occurring in instructional technologies. The intertwining of these two trends suggests that the future relationship between assessment and technologies, and between assessment and instruction, will be far different from that of the past (Baker and O'Neil 1995).

During the last decade, instructional uses of information technologies have increased in sophistication and depth, to the point that many K–12 classrooms are now sophisticated users of technology. Primary school students are learning to use digital cameras, scanners, word processors, CD-ROMs, computer graphics, and other tools. Older students are learning how to work with hypermedia, communications, models and simulations, and other technologies that adults routinely use in their work.

The goals of technology-enhanced learning go well beyond familiarity with technology tools as an end in itself. Students are using information technologies to facilitate learning in a variety of disciplines. Students write using a word processor, retrieve information from CD-ROMs and the Internet, compute using a calculator or spreadsheet, organize information in a database, and develop multimedia presentations using computer-generated graphics and by creating websites. In the process, they not only learn more about the subject they are studying, but they also develop their higher-order cognitive skills and problem-solving abilities.

Measuring technology-enhanced learning: examples for consideration

Effective measurement of technology-enhanced learning has many components. First, teachers must understand and model the use of the technology in relation to the subject matter that their students are to learn. Second, student assessment must reflect both the discipline and its successful integration with the information technologies acquired through technology-enhanced learning. Illustrations follow.

If, for example, educators want students to learn to develop documents that communicate effectively, then the teacher should model the tools of professional communication, employing both writing skills and document design applications. The teacher should integrate writing, editing, and critiquing with document design tools such as word processing, projection equipment, and desktop publishing software. In following the teacher's model, students produce their own documents. The students' final documents then serve as assessment instruments for both the subject and its application.

Or suppose educators want students to make effective use of calculators or computers to help them solve mathematics, science, and social science problems. Test designers develop assessments that assume students will have access to calculators or computers when they are being assessed. Educators design curriculum and instruction that helps students learn to function comfortably and competently in environments with routine access to these tools. The teacher models the desired performance in the instruction. The curriculum includes emphasis on roles that calculators and computers play in "knowing and doing" the discipline being covered.

Or imagine that educators want students to develop multimedia presentations that can be used with a small group or a whole class. The multimedia presentation—in essence, a "performance"—is the final product to be assessed. In this situation, the teacher should model these kinds of presentations. Students should routinely view teacher-created multimedia presentations as a routine part of the instructional process, and the various components of multimedia communication and presentation should be thoroughly covered in the curriculum.

In order then to measure student achievement in technology-integrated instruction, the assessment methods should reflect both the academic discipline and the technological skills that students have acquired. Further, teachers must also be adequately prepared both to model and to assess the students' technologically-integrated results.

Technology-Based Assessment Tools and Processes

Information technologies can add to the assessment process in two basic ways. First, they can improve the efficiency and technical qualities of existing forms of assessments. For example, the technologies can make it easier and faster to develop, administer, and score conventional tests; to collect and analyze student work; and to produce grades and progress reports. Second, the technologies can extend assessment in directions not possible before. For example, they can make it possible to measure complex skills, processes, and performances that were heretofore unmeasurable, or they can create computer-based environments in which assessment is embedded in the learning process (Chung and Baker 1997). These latter options are among the most compelling reasons to use technology as part of assessment.

Below are several examples of new technology-based assessment tools and processes. They include

Tools and processes of technology-based assessment

- **computer-generated and computer-scored tests;**
- **computer-presented and computer-adaptive tests;**
- **electronic gradebooks;**
- **electronic portfolios;**
- **simulations and knowledge representation;**
- **process-based projects.**

Some are intended primarily to improve existing modes of assessment, while others open up new modes of assessment. Some can do both and point to the potential for enhanced student learning through the use of information technologies, especially in project-based learning.

Computer-Generated and Computer-Scored Tests

Conventional standardized tests composed of multiple-choice, true-false, or similar items, are familiar and common assessment methods. Computer technology can be quite useful in developing, administering, and scoring these kinds of tests.

Technological enhancement of familiar assessment methods

Information technologies can be used to organize and select test questions from large data banks of items, even if the test is to be administered with paper and pencil. Suppose, for example, you are testing large numbers of students and you want to produce three different forms of a test with the same level of difficulty. With simple test-generation software, the computer can be directed to produce three randomized versions of the test with the same questions but in different order. Or, it could produce versions with different questions but the same level of difficulty by selecting different subsets of items from the computerized data bank.

Computers can also be used to generate test questions. For example, to measure mathematical computation skills, a computer can be programmed to generate numbers randomly to be used in a certain type of problem and then to solve the problem. Careful program design and sophisticated programming techniques make such item-generation software applicable in a wide range of testing situations. With computer-generated test items, it is possible to generate innumerable tests of essentially the same difficulty and coverage. This is useful when students need to take makeup tests or take tests at varying times to assess whether they have mastered a certain skill. A test on a topic can be generated, printed out, and given to the student whenever it is needed.

Technology can also help with administering and scoring tests. Conventional tests commonly use "scan sheets" on which students record their answers. A scanner/computer can process the sheets quickly and accurately. Later the computer can be programmed to analyze items and performance patterns—for example, by providing data on how often each question was answered correctly or which questions best discriminate between high-scoring and low-scoring students. These analyses can then be used to refine test questions and produce a better test.

Computer-Presented and Computer-Adaptive Tests

Computer technologies also make it possible to store, administer, and score tests or test items in a variety of formats. Computer-administered tests can present questions that use text, graphics, color, sound, animation, and video. Depending on the available hardware and software, a student might respond using a keyboard, mouse, touch screen, voice, or adaptive device designed to fit the needs of a student with a particular disability. If the computer-presented test does not have open-ended questions, scoring can be immediate—indeed, if desired, a report can be given to a student as soon as she completes the test. Moreover, the computer system can gather data on the time spent on the various test items, changes in responses when the student reexamines an item, and so on. The availability of this sort of data from numerous test takers provides a basis for analyzing both the individual tests items and the test-taking process of each student.

"Computer-adaptive testing" (CAT), a particular type of computer-presented testing, is gaining wider use in large-scale testing programs. CAT is interactive, adjusting the student's test questions as the test proceeds. The computer selects questions for an individual test taker from a large bank of items. The questions are tailored to the test taker's ability, based on his answers to previous questions. For example, if the student begins to answer incorrectly most questions of a certain level of difficulty, the computer will switch to providing easier questions. The goal is to assess what a student knows with fewer questions, omitting questions that are clearly too easy or too hard for that test taker.

Technological enhancements to testing formats

It requires considerable resources to develop and adequately test a CAT product. For this reason, these tests are typically developed by large school districts, states, or national or commercial testing services. The Educational Testing Service (ETS) has already implemented computer-adaptive testing to replace the paper-and-pencil versions of the GRE and certain other advanced tests, and offers computerized versions of SAT, PRAXIS, and other tests.

Computer-adaptive testing: CAT

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CAT has been the subject of considerable research. Generally speaking, CAT is quite a bit faster than paper-and-pencil testing, primarily because students do not need to answer as many questions to provide a good measure of their performance levels. Other advantages noted by ETS are more flexible scheduling of large-scale tests; greater privacy for students, who can take the tests in smaller groups; and the opportunity to get an unofficial score report immediately. ETS also asserts that students do not need prior computer experience because they can go through a computer tutorial program before the test begins (Educational Testing Service 1998).

Studies have also found that well-designed CAT can outperform the validity and reliability of paper-and-pencil tests for students at the extreme ends of the population being tested. For example, some seventh graders who take a statewide reading comprehension test may read below the third-grade level, and some may read above the eleventh-grade level. Most of the questions in a paper-and-pencil test for seventh graders are at the fifth- through ninth-grade levels. CAT readily adapts to students falling outside this range and asks questions that can be used to assess accurately their actual performance levels (Shermis, Stemmer, and Webb 1996).

Disadvantages of CAT

Other analysts, however, have criticized certain aspects of CAT and contend that the research evidence supporting it is overstated (FairTest 1998). In a computer-adaptive test, students cannot change their answers to previous questions, skip questions and go back to them later, or underline or scratch out eliminated choices—things that are easy to do in paper-and-pencil tests. Further, critics assert, CAT may be more biased than conventional modes of test administration, favoring higher-income students or boys, for example, who have greater access to home computers.

Nevertheless, computer-presented tests have expanded assessment options, especially since many schools now have adequate computer facilities to use them. The software necessary to do simple computer-presented testing, such as drawing items randomly from a data bank, will run on even the simplest computers. Thus, computer-presented assessments can be used by any teacher who has an interest in developing the necessary data bank of test items. Moreover, many textbook publishers have developed such item banks and provide them with classroom-sized orders of textbooks.

Students may find that computerized testing offers a flexibility not readily available in paper-and-pencil testing. If the computer can generate test questions or retrieve them from a data base, individual students can take tests whenever they are ready to do so, rather than when the test happens to be scheduled for a whole class. This can help support individualized instruction and mastery-learning approaches to education. Computerized testing can also better accommodate some students with disabilities, who may require input devices not available in paper-and-pencil testing.

Flexibility of CAT

Electronic Gradebooks

Many teachers use electronic grade books, which enable them to keep detailed records, write notes to parents, provide students with current information about their grades and their progress toward course standards, and produce end-of-term grades and student reports. Over the years, electronic gradebook software has become more sophisticated and versatile. It is now possible for teachers to develop non-linear seating charts, store alias names for students so that grades can be posted with privacy, give different weights to various assignments and tests, and adjust for excused student absences. In most electronic grade books, teachers can also enter anecdotal information and other written comments.

An electronic gradebook may be installed on a laptop computer or personal digital assistant that a teacher can use when making the rounds to observe students at work. The teacher can use checklists to make observations of student behavior and performances, entering notes as needed. A teacher needs training and experience to use these tools effectively.

Technology applications for instructional management

Electronic Portfolios

Long a preferred method of assessment in the visual arts, the idea of assembling and critiquing portfolios of students' work is becoming a more common assessment strategy in a variety of disciplines (Gardner 1993; Fogarty 1996). A portfolio might contain, for example, writing samples that illustrate changes in a student's writing skills over time, analyses of science experiments, videotaped presentations, or multimedia products developed on the computer.

Multimedia possibilities in student portfolios

In portfolio assessment, the student and teacher together select appropriate items, often choosing more than will finally be used. Together, the student and teacher assemble a presentation portfolio for a specific purpose, such as making a presentation to parents. As an important part of the process, students are asked to develop a critical analysis of the works that have been selected. This analysis might discuss the purposes of the various portfolio items, as well as the progression in knowledge and skills demonstrated by the sequence of items.

Information technologies add new dimensions to portfolio assessment. First, technology can be used to digitize and store pictures, graphics, sound, and text. Computer editing facilities can be used to arrange the portfolio items into various kinds of presentations, each geared to a different situation or audience. Second, many students now carry out projects and create products that can only be adequately represented and used on a computer. Examples include interactive multimedia "stacks," Web pages, computer-synthesized music, science simulations, and complex mathematical problems.

Electronic portfolios: assets and drawbacks

Electronic portfolios have some advantages and disadvantages over traditional collections of papers and physical products. In many cases, technology makes it easier to edit, copy, store, and move the materials. The documentation can be shared among teachers and across sites. Video technologies can record student presentations for critique, reflection, and outside viewing, an application that produced dramatic improvements in the presentations of shy, inhibited, and troubled students, in the *Learning Tomorrow* program supported by the National Foundation for the Improvement of Education (Hawkins, Baker, Justin 1998). But electronic portfolios also have drawbacks. To view them one must have the appropriate hardware, software, knowledge, and skills. Moreover, the hardware and software used to create an electronic portfolio eventually become obsolete, and long-term records have to be translated to current media and software formats from time to time if they are to remain easily accessible.

Simulations and Knowledge Representation

A promising form of assessment has emerged from computer-based software that enables students to construct models or representations or to interact with rich environments that simulate a real-world context or problem. These tools allow students to respond in different ways to a set of interrelated conditions. Students can be given open-ended tasks of varying complexity. For example, students might be asked to develop hypermedia concept maps that show the relationships among the policies and events of the Great Depression, or they might interact with a computer microworld to explore the food chain (Baker and O'Neil 1995).

Assessing student understanding of concepts

How students choose to respond or to represent their knowledge opens a window on their conceptual understanding (Vitale and Romance 1995). These types of problems can be a form of assessment in themselves, because they provide a visible representation of students' knowledge and thinking processes. By viewing students' representations or tracking their simulations, teachers can see which concepts students understand, which they do not, and where they have used flawed reasoning. By reviewing subsequent versions of a model, teachers can see how students approached a problem and how they refined their thinking over time.

According to evidence from a study of the *Apple Classrooms of Tomorrow* project, representation tools may be especially useful for unlocking the understanding of students who are poor writers or speakers. A small group of students participating in this project had poor essay scores and mediocre reading skills and performed below expectations on standardized tests, but with HyperCard software, they prepared elaborate knowledge representations that showed strong understanding of certain concepts (Baker and O'Neil 1995).

Software-embedded assessment

The Center for Research on Evaluation, Standards, and Student Testing is developing software that can be used to measure students' thinking processes as they undertake complex tasks. One such project allows teachers to embed assessment points into the process of creating a concept map (a diagram that shows how key concepts within a certain domain of knowledge are related to each other). With this type of software, educators could program the computer to store data about how students choose to do a computerized search, how they develop their concept maps over time, or which concept links they create, modify, or delete. All of these stages form an assessment point. These kinds of assessments have the potential to be unobtrusive and inexpensive (Chung and Baker 1997).

Process-Based Projects

New methods of instruction emphasize the importance of engaging students in long-term projects that draw upon a range of complex skills. In this type of instruction, students learn by going through the process of planning and designing their projects, receiving feedback at various stages, reflecting and revising, and completing a final product. The writing process is one such example. Students learn that writing begins with brainstorming and other pre-writing activities. Students then go through repeated cycles of composing, receiving feedback, and revising. Finally, they polish their writing for final publication. Conducting science experiments is another example. All produce final products that are published or performed (International Society for Technology in Education 1996).

Project-based learning and sequential, continual assessment

Continual assessment is built into these kinds of projects. The stages of giving and receiving feedback, reflecting on one's own work, critiquing the work of others, revising the developing product, and presenting a final product could all be considered forms of assessment. These projects enable teachers to assess students' habits of mind and patterns of performance as they increase their expertise. In effective projects, the criteria for success are clear and understandable to the student. A student learns to engage in an internal dialogue that is guided by assessment criteria, both those set by the external evaluator and those that the student considers of particular importance.

Information technologies are playing an ever-growing role in project-based learning. In many schools, students use technology to collect, process, and communicate information for their projects and to develop high-quality products and performances. A sequence of drafts of the project may be stored in a computer, becoming part of an electronic portfolio. This means, however, that teachers must be skilled in the technology, must know how to apply it to assessment, and must be able to guide students through self-assessment and peer assessment. In many cases, the information technologies enable students to achieve higher levels of performance than they could without the technology.

How Technology Can Add to Assessment

As several of the examples above illustrate, information technologies can enhance assessment in ways that are compatible with authentic approaches to instruction and that encourage the high levels of student learning envisioned in standards-based reform. Particularly noteworthy are the following characteristics:

Advantages of technology-enhanced assessment

- **Technology can provide a more faithful representation of real-world tools, contexts, and problems. Students can use the actual technological tools of a particular field. They can explore and assess situations and problems that are much like those adults face on the job, at home, and in other everyday activities. With computer networks, students can access the same information as professional researchers. They can communicate and can share assessments to date with their peers in the same way that colleagues interact at work. As in adult life, students can also use technology to collaborate on projects that can only be accomplished by a group.**

- **Technology makes it feasible for students to study problems more complex and compelling than those they could otherwise undertake in school because of the power to retrieve, store, and manipulate large amounts of data. Often these problems cut across several disciplines, involve many steps, and have many possible solutions.**

- **Technology can develop students' higher-order cognitive skills and encourage their creativity. It can make more transparent both the students' habits of mind and the thinking patterns they use to solve problems.**

- **Technology can emphasize the process as well as the product, allowing students to carry out multistage tasks with greater facility, building on an assessment at each stage.**

- **Technology can facilitate self-assessment by enabling students to work through multiple cycles of feedback, reflection, and revision.**

- **Technology can embed assessment within the instructional process. Technology lends itself to the kinds of continuous assessments found in authentic assessment, which reveal more than the "one-shot" approach typified by conventional tests.**

Simply using information technologies for assessment does not guarantee that these characteristics will be present. As explained in the next section, realizing the potential of technology-based assessments requires attention to several key issues.

Issues in Technology-Based Assessment

As with any type of assessment, the quality of technology-based assessments will depend on how well they are designed and implemented. Developers and users of technology-based assessment must be attentive to the same technical considerations as those involved in other kinds of assessment. They must also consider a whole new set of issues related specifically to information technologies. Some of the major issues are

Successful technology-based assessment requires quality design and implementation

- **measurement quality and research needs;**

- **trained assessor judgment;**

- **professional development and community education;**

- **alignment with curriculum and instruction.**

Measurement Quality and Research Needs

Authentic assessments that involve technologies must still meet high standards of measurement quality. This is particularly true with assessments used on a wide scale or with high stakes attached. Merely adding technology to a weak or inappropriate assessment strategy will not solve its problems, and it may compound them.

New assessment methods must be developed, evaluated, and piloted from a measurement standpoint, not just from a technology standpoint (Chung and Baker 1997). In fact, an analysis of such characteristics as validity, reliability, and fairness may become even more complex with new forms of assessment because we do not have decades of data to rely on as we do with conventional forms of standardized testing.

Determining appropriate and valid assessments

Many important measurement questions have not yet been resolved with certain kinds of technology-based assessment. For example, the same students may perform differently on assessments with paper and pencil than they do with computer-based assessments of the same content areas. Further, research is needed to determine whether different skills are being assessed, how the technology might mediate the outcome, or whether other factors are responsible for these differences. This is just one of the many measurement issues now being studied for technology-based assessments. Moreover, some of the most promising applications of technology to assessment are not yet available as off-the-shelf products (Chung and Baker 1997); they must undergo further research and development before they will be ready for wide-scale classroom use.

The fact that the research base is incomplete does not preclude teachers from using technology-based assessments. It does suggest, however, that many such approaches may not be ready for use in high-stakes decisions. It also suggests that educators consider the following kinds of questions in deciding whether to use a particular assessment in their classrooms (Vitale and Romance 1995):

Questions for guiding assessment choices

- **Is this type of test appropriate for the intended use? For example, should the results be used only in the classroom, or can they be shared with an external audience, which might use them to make various inferences?**
- **How well does it match the goals of the instructional program?**
- **Is it adding something qualitative to teaching, learning, or assessment?**
- **Is it practical and cost effective?**

Trained Assessor Judgment

For authentic assessments to be effective, students, teachers, and other assessors must be aware of and trained in appropriate criteria for assessing a piece of student work. It can be very helpful to have some consulting help from an outside assessor who has a higher level of expertise in the student work being assessed.

Qualities for judging student work

Judging student work as part of a formal authentic assessment demands a high level of competence and training. To achieve reasonably reliable results, several people should assess a student product and mechanisms must exist for resolving discrepancies. (Anyone who has watched the scoring of athletic performances in diving, gymnastics, or ice skating is familiar with this situation. Each performance is scored by multiple judges, often with the highest and lowest score being thrown out. A head judge may call the judges together for a discussion to resolve discrepancies.)

Applying rubrics

Learning to apply rubrics is a key part of learning how to judge student work. A rubric is a scoring tool that can be used by students and their peers or by teachers and evaluators. It lists important criteria applicable to a particular type or piece of work, along with varying levels of possible achievement of the criteria. For example, a writing rubric may be designed to assess which of the following six categories best characterizes a student's writing skills, as evidenced in a piece of writing: emergent writer, limited writer, developing writer, capable writer, strong writer, or exceptional writer. Each of the six levels is accompanied by several criteria that describe writing at that level. As part of their training, assessors examine many pieces of writing and learn how to apply the various criteria associated with each level.

Rubrics have been developed and published for many different curriculum areas (Brewer 1996). Extensive research has been done on their effectiveness and on ways to educate teachers how to use them effectively. These studies have found that

Characteristics of rubrics

- **developing good rubrics is a difficult process that requires attention to both the end result and the process (Wiggins 1996-97);**
- **rubrics alone do not lead to educational improvement without compatible changes in curriculum, instruction, and assessment and a substantial amount of professional development;**
- **teachers need to learn to modify the scoring rubrics that are published in books and articles to better fit the learning needs of their students, and they need to learn to develop rubrics.**

Professional Development and Community Education

Challenge:
authentic assessment from a technology viewpoint

There is a considerable need for professional development in new assessment technologies. Teachers in all disciplines will eventually have to work with and be able to assess students who are making routine use of information technologies. This means that teachers and students are learning three things at once: how to use the technologies, how to integrate them into teaching and learning, and how to apply them to assessment. Although some schools and school districts have devoted considerable professional development time to authentic assessment, few have addressed this topic specifically from a technology point of view. The addition of information technologies makes the already complex process of authentic assessment even more challenging.

Teachers' views of assesement

Studies of technology-integrated learning projects indicate directions for professional development, as well as other supports that must be present. In technology integration efforts funded through NFIE's *Learning Tomorrow* program (Hawkins, Baker Justin 1998), the studies suggest that many teachers are insecure about their understanding of technology-based assessment. For example, many teachers reported they had little knowledge of assessment issues. Yet other evidence suggested that many were actually collecting and analyzing student data in ways that were consistent with the project's assessment goals. At one project site, teachers expressed the feeling that assessment in general was inappropriate for younger children and that asking young students to reflect on their work was also inappropriate. These teachers tended to view assessment as a static event rather than as a process of evaluating students' works over time. These findings suggest that, in addition to insecurities about their understanding of technology-based assessment, many teachers do not recognize that much of what they do in their classrooms already represents a dynamic form of assessing student learning.

Need for time for professional development

Time is a critical need—time to participate in professional development, time to learn how to apply new knowledge in the classroom, and time to actually implement new methods of assessment. This is particularly so with authentic assessment; learning how to document and make judgments about students' works is a lengthy process in itself, and doing the actual documentation and judging takes longer than giving a conventional test. In NFIE's *Learning Tomorrow* program, many teachers had trouble keeping up with the required documentation of their assessment activities, and few participated in organized online discussions about assessment, primarily because both took time away from implementation activities (Hawkins, Baker, Justin 1998).

Need for time to learn how to apply new technology assessment methods

Teachers are not the only ones who require education about new practices. The introduction of authentic assessment into a classroom, school, or school district may encounter considerable resistance from parents, students, and other key stakeholders. It represents a substantial change from conventional assessment, and many people oppose such change. As with any school reform project, all of the key stakeholders need to be involved. There must be considerable emphasis on helping the stakeholders learn about the advantages of authentic assessment, particularly if it involves technology, as well as the difficulties and drawbacks.

Alignment with Curriculum and Instruction

Wide use of technology-based authentic assessment requires changes in curriculum and instruction

Authentic assessment—especially as it relates to information technologies—is an essential component of school reform, but its wider use will require complementary changes in curriculum and instruction. Curriculum and instruction should focus on the important knowledge and skills that students are expected to learn, and assessment should measure the same knowledge and skills. All three should stress critical thinking skills, creativity, and habits of mind that support lifelong learning and consistently high levels of performance. When curriculum, instruction, and assessment are aligned, the issue of whether assessment is driving curriculum and instruction becomes less of a concern.

Many schools that participated in *The Road Ahead* program came to realize that their existing methods of assessment were not aligned with the kinds of student outcomes they were seeking through technology-based learning (ISTE 1998). Other research suggests, however, that technology-based projects can successfully adapt their assessment methods to bring them more in line with their technology-enhanced curriculum (Hawkins, Baker, Justin 1998).

Final Remarks

With technology, students can expand their knowledge and develop their higher-order cognitive skills by addressing real-world projects and complex problems, but the full realization of these benefits will require compatible changes in assessment. Information technologies can also help with that. Not only can technologies improve the efficiency of current assessments, but they also can offer new ways of measuring student learning. Successful implementation of technology-based assessment requires research and development on their measurement aspects, professional development and other supports for teachers and key stakeholders, and compatible changes in curriculum and instruction.

"Assessment and Information Technologies in the K–12 Curriculum" is one of several papers included in *Connecting the Bits, A reference for using technology in teaching and learning in K–12 schools*, issued by the National Foundation for the Improvement of Education in 2000, and available at www.nfie.org.

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Professional Development and Information Technologies

Introduction

Information technologies must play an important part in the education of America's children. Parents, students, and educators are united in the belief that a technologically rich curriculum is an essential component in preparing today's students for adulthood in the new millennium.

Schools are being wired. Many schools already have Internet connectivity; many also have their own local area networks. Further, local, state, and federal agencies are rapidly committing to connect every school classroom to the Internet.

There is wide public support for application of information technologies in education. Everyone wants students to use computers in schools. Yet, beyond computer literacy and willingness to learn new technologies, society has only the vaguest notion of what students should accomplish. The public understands little about how information technologies can most effectively enhance student learning and relies on educators to make prudent use of the considerable public investment in wiring the nation's schools.

Early efforts to integrate information technologies into the curriculum were pioneered by technologically literate teachers and educational researchers. Demonstrating both the practice and its effectiveness, their results helped galvanize the resolve of state and local districts to integrate technology and education. The goal was to enable large numbers of students to benefit from the technological revolution and its limitless contributions.

This paper discusses

- the need for technology-related professional development and the difficulty of integrating technology into teaching and learning;
- the key characteristics of high-quality professional development and their implications for technology;
- strategies for professional development that have promise for improving teacher knowledge and skills in technology;
- support, access, and structures that must be in place to help teachers make the most of technology-related professional development;
- assessment of the effectiveness of technology-based professional development;
- the promise of technology for improving professional development;
- an annotated bibliography.

As classrooms are wired, it is teachers who face the main challenge of figuring out how best to incorporate technology into their practice. They look to professional development to help them fulfill that mission. In a 1996 national poll conducted by the National Foundation for the Improvement of Education (NFIE), 93 percent of teachers placed "how to use information technologies for instructional purposes" as a top priority in striving for their overarching goal: helping students achieve. In survey after survey, these findings are consistent. Teachers recognize the importance of tapping into technology's vast promise for enhancing teaching and learning, and they want to do it right.

One-shot workshops are not the answer

Knowing how to integrate technology into the curriculum is a complex challenge. It will not be met by one-shot workshops. Instead, truly effective professional development in technology applications for educators is marked by several key components. Technologically proficient teaching and learning requires that teachers participate in ongoing individual and collegial study, reflective thinking, analysis of practice, and evaluation of student achievement. Such deep learning is job-embedded, rigorous, and systemically sustained—three hallmarks that differentiate solid, results-oriented professional development from the limited training reflected in much current practice.

Teacher learning is the key

NFIE focused on professional development as its primary strategy for exploring the best practice in the groundbreaking collaborations of its *Road Ahead* program. In this focus, NFIE drew upon decades of research and evaluation of what constitutes high-quality professional development. Consistently, the findings indicate that it is what teachers know and can do that makes the difference in improved student performance and that teacher learning is the key to helping students achieve. NFIE, the National Staff Development Council, and other groups have written extensively on this topic.

Mentors and online networks

Two additional components augmented the strategy focusing on professional development in these school/community partnerships. The first was assigning experienced teacher mentors to each project site. Drawn from the ranks of successful NFIE grantees, these mentors had expertise relevant to the site's program but did not live in the same region. The second was developing online networks to facilitate communication among mentors, site teams, NFIE staff, and others who played a part in providing resources and support.

36 percent of budgets for professional development

The Road Ahead sites devoted an average of 36 percent of their grant budgets to professional development—a figure consistent with recommendations from research that schools spend about a dollar on technology-related professional development for every two dollars spent on technology acquisition and implementation (ISTE 1998). The total funding for professional development in *The Road Ahead* program was actually greater, because NFIE also conducted three national conferences for all the project teams as a main component of its professional development strategy.

This paper discusses recommendations for effective professional development resulting in technologically proficient teaching and learning. It is based on extensive research, collaboration among accomplished experts in technology education and practitioners in the field, and the results of the real-life application of these innovative programs. The discussion is centered upon field-tested programs and reflects the input of all that were involved in the programs' execution.

The Need for Technology-Based Professional Development

Technology can be a catalyst for changing how teachers teach, what they teach, and how they interact with students. It can also simplify routine responsibilities, thus freeing time for teachers by helping them and their students to work more efficiently.

Technology can facilitate teaching methods that build students' inquiry and problem-solving skills and their content knowledge in every subject. For example, students can gain access to a wealth of research sources and experts via the Internet, manipulate complex dynamic models and simulations, work cooperatively in small groups with portable technology, use multimedia tools to present what they have learned, and collaborate on projects with students around the world. Technology can accelerate changes in teacher roles, such as moving away from a lecture mode of instruction to one in which teachers coach students in solving complex, real-world problems.

When a teacher finds herself in a classroom with six computers, Internet connectivity, a wide array of software, and a mandate to integrate them into her teaching, the reaction may well be confusion, discomfort, or even fear. It is this very variety, flexibility, and complexity of technology that make it more difficult for teachers than other topics of professional development.

Special challenges for teacher professional development in technology

There are special challenges associated with learning how to use information technologies that are not present with other educational tools. When educational television programming was introduced a few decades ago, teachers could learn within minutes how to operate the hardware—turn on the set, change the channel, adjust the picture, etc.—and view the programming. They could begin right away to focus on the content. They had no control over software, and it was not interactive. Familiar and comfortable instructional techniques could be used to prepare students for viewing and debriefing them about the content of the program afterwards.

Familiarity and facility of use

With computer-based technology, however, operational aspects take time to learn and still more time to practice and explore before the technology becomes familiar enough that teachers can truly attend to the content of learning. Teachers must learn how to use the technology itself at the same time they learn how to integrate it into their teaching. Also, because hardware, software, and applications change so rapidly, even teachers who are adept users of technology must pay constant attention to the basic operational procedures of new applications.

It is little wonder that many teachers are apprehensive. For all but a few new teachers, technology was not a routine part of their own preparation, and many have had limited formal training in or experience with using it. It is not unusual for students to be more comfortable and competent users of technology than their teachers are, which itself can be a cause for teacher discomfort. Conversely, it is also possible for teachers to tap into students' technology skills, creating an atmosphere that concentrates on multiple ways of sharing knowledge.

In 1998, 20–24 percent of teachers felt "well prepared" to integrate technology into the classroom

In a 1998 survey by the U.S. Department of Education, 78 percent of teachers reported that they had participated in professional development about integrating technology into the grade or subject they taught during the last twelve months. Yet despite this level of participation, only 20 percent said they felt very well prepared to integrate technology into classroom instruction, and another 37 percent said they were moderately well prepared. The figures were only slightly higher for teachers with three years or fewer experience; 24 percent of this group said they felt very well prepared.

Although need for professional development in technology is great, investments in high-quality professional development for technology can begin paying off relatively quickly. Several *Road Ahead* projects reported that teachers started integrating technology skills into their teaching almost immediately after professional development experiences.

Characteristics of High-Quality Professional Development

Whether technology will produce the deep, long-term, and systemic changes hoped for will depend greatly on the quality of the professional growth experiences in which teachers engage. Many people still think of professional development as one time "events," like workshops, that take place on designated days. But as research over the past decade has shown, short-term activities that focus on building discrete skills do little to promote lasting improvement if they are not linked to more sustained and collegial opportunities for professional learning. This is especially true where technology is concerned.

Effective professional development is linked to sustained collegial teacher learning

Professional development has been a primary focus of NFIE throughout its thirty-year existence, and the foundation has learned a great deal from developing and analyzing its various programs of grants to educators. Based on this experience, NFIE has identified ten characteristics associated with high-quality professional development that apply to technology as well as any skill or content area.

These characteristics, which are explained fully in the report *Teachers Take Charge of Their Learning* (NFIE 1996), are similar to those identified by other groups with a longstanding interest in teacher professional development, including the U.S. Department of Education.

Below is an abridged list of key characteristics that mark high-quality professional development, adapted from the NFIE list and other sources. They are discussed in relation to their particular implications for technology, with concrete examples of their successful application from specific *Road Ahead* sites.

Key characteristics of high-quality professional development

Effective professional development efforts are

- **focused on student learning;**
- **designed and directed by teachers themselves, incorporating teacher needs.**

In addition, they

- **are rigorous and sustained over time;**
- **are realistic and visionary;**
- **build collegial professional culture.**

A Focus on Student Learning

High-quality professional development has at its heart the goal of improving student learning. Certainly, helping students become proficient users of technology can be one goal of technology-related teaching and learning, but as the primary goal, it falls far short of its ultimate best applications.

Educators must be able to use technology to further student learning in subject matter, such as science, mathematics, language arts, and other areas addressed in state and local content standards. In addition, educators must help students to extend their information technology strengths to nurture the habits of mind that support critical thinking.

Technology to further student learning in specific subject matter addressed in state and local content standards

The challenge, then, is to design professional development experiences that encourage teachers to incorporate technology into rigorous curricula and instruction.

Teachers are more likely to care about hardware and software when they can connect it with what goes on in their classrooms. Rather than centering professional development on hardware and software, educators should begin by looking at what students should learn. Then they can better determine the ways in which technology can support that learning and make it more effective (SEIR-TEC 1999).

Another approach is for teachers to look at how students can learn. Such an approach begins with a particular instructional strategy that will improve student performance. For example, in the Franklin, Tennessee, *Road Ahead* site, the goal was to use a project-based approach to teach science. After the strategy was defined, the teachers explored ways that technology could serve the educational objectives.

Professional development that is truly focused on student learning and employs technology as an educational tool must be attentive to the needs of students with diverse learning styles. Moreover, it considers effective methods of teaching students from a variety of cultural, linguistic, and socioeconomic backgrounds.

When technology is viewed as a servant to increasing knowledge, the integration of technology into the curriculum can open new opportunities for effectively teaching diverse learners. For example, the ability to manipulate visual representations of scientific or mathematical data on a computer can help visual learners to grasp concepts they find difficult to understand when those concepts are explained on the written page.

Increase of student motivation

In addition, when students must present a report that will be posted on the Internet, they are often more motivated to organize their work, attend to its accuracy, and provide a clear description. They can also be more creative when using presentation software to produce results that can be viewed by a worldwide audience.

A specific example of technology tailored to adapt to various learning styles may be seen in the *Road Ahead* project at Rice Creek Elementary School in Columbia, South Carolina. As a part of its professional development, the staff examined the learning styles of students in its school and wrote goals for a new curriculum. The results helped to create a three-year plan to revise and integrate technology into a curriculum based on multiple learning styles. The process of working together in groups to conduct research was rich professional development that led to actual changes in classroom instruction.

Expanding learning for diverse student populations

Technology can also expand learning opportunities for students from many ethnic and socioeconomic backgrounds. Many *Road Ahead* sites had ethnically and racially diverse school populations, and their projects were focused on improving the achievement of particular groups that were not performing up to expectations. At Alvarado Elementary School in Union City, California, the ultimate goal of professional development was to improve students' science learning, especially among girls and African-American and Latino students. The project in South Mountain High School in Phoenix, Arizona, sought to boost the achievement of Latino and African-American students, many of whom came from low-income families. Professional development in this school focused on helping teachers to incorporate technology into its Academic Decathlon competition and to use the Internet to expand the horizons of students who had seldom traveled outside their community.

Designed and Directed by Teachers, Incorporating Teacher Needs

One of the major findings from research and practice over the past decade is that professional development is more effective when it is designed and directed by teachers, rather than developed and delivered by central administration. Teachers know what they need in order to do their jobs better, and they are more likely to make a personal commitment to their own professional growth when they are involved in conceiving professional development and carrying it out.

Teacher-directed professional development

The process of taking charge of one's own learning can be very empowering. It begins when teachers realize that they have knowledge worth sharing. It continues as they develop their knowledge and intellectual skills. It is augmented when they share their knowledge and skills with colleagues. It is amplified when they help one another professionally. It is sustained by the climate of collegial professional support that is the result.

Through such participation, teachers build their own leadership skills and empower themselves to take charge of their learning. In doing so, teachers also model the principles, the practice, and the effectiveness of self-directed learning, which is the behavior that they ultimately hope to nurture in their own students—to become self-directed, life-long learners.

Teacher-directed professional development was a fundamental principle of *The Road Ahead* program. In this type of professional development, teachers have a strong say in the issues to be addressed, the target group, the format, and the intensity. At Phoenix's South Mountain High School, for example, topics for professional development were derived from a school-wide survey of what teachers wanted to learn. The technology coaches of South Mountain were familiar with learning needs of the district's students. They understood the idiosyncrasies of the district's network and were aware of other specifics of the work environment. Thus, they were able to bring practical examples and contextual richness to the school's professional development and through that contribution, to establish credibility that no outside trainer could ever approach.

Teacher-determined issues, target groups, formats, and intensity

Teachers teaching teachers is a common model for teacher-directed professional development and was the dominant strategy used in *The Road Ahead* program. This model of developing cadres of skilled teachers is sometimes misunderstood. Schools may send a few teachers to a conference or workshop, then expect them to come back and immediately train a sizable group of colleagues in whatever new skills and knowledge they acquired. This approach seldom works, especially for technology, for many reasons: the content is too complex to master in a short time, no follow-up is provided, and the would-be trainers may not be experienced in organizing professional development for their colleagues (SEIR-TEC 1999).

Teachers teaching teachers: successful models

High-quality professional development programs build in time and incentives for teachers to reach a level of mastery and develop leadership competencies. The initial professional development made available to *The Road Ahead* team at Alvarado Elementary in Union City, California, had a ripple effect, thanks to an extended block of time once a week for technology-related professional development (Moursund et al. 1997-98). By the end of the third project year, more than twenty teachers had become coaches in technology for other teachers.

Rice Creek Elementary in Columbia, South Carolina, took a different route with its project by arranging for a University of South Carolina professor to teach a semester-long, three-hour graduate course in the school's computer lab. Because so many teachers participated in this class, they began working together to solve problems right away. The team soon realized there was no reason to designate a special cadre of teacher trainers.

Rigorous and Sustained over Time

High-quality professional development is rigorous. It aims to sharpen teachers' intellectual skills, deepen their subject-matter knowledge, and improve their understanding of learning. To accomplish this, participants must be able to concentrate, reflect, and study—behaviors that are difficult to apply in the middle of a busy classroom.

Professional development: sustained and meaningfully intense

It takes time for teachers to master new technologies and still more time to consider, try out, and integrate new approaches into their practice. In the past, much of the technology training teachers received was informal, such as advice from technologically adept teachers who found themselves filling the role of technology guru. Formal activities usually consisted of a workshop on a self-contained skill, such as using a certain software package. Increasingly, however, educators and researchers have come to see the need for professional development that is structured, sustained, and meaningfully intense.

According to a U.S. Department of Education survey, 38 percent of teachers who participated in more than eight hours of professional development in technology during the last twelve months said it improved their teaching "a lot." In contrast, only 12 percent of teachers reported similar improvement with eight or fewer hours.

Three to five years for implementing changes in practice

Both the school reform literature and the practical experience of *Road Ahead* grantees strongly indicate that it takes three to five years to implement changes in practice built around new technologies. Often with technology, one of the principal goals is to change teachers' fundamental beliefs and attitudes. To attain that goal, teachers need adequate time to discuss the implications of new beliefs, reflect on their practice, formulate new visions for where they are heading, find new methods of assessing progress, and develop new working relationships with peers, mentors, and others (Parsons 1998b).

Continuing support required for teacher-led professional development

It follows logically, then, that professional development for technology integration may need to be sustained for a period of years. Such professional development will require continuing support as teachers implement new ideas in their classrooms. In addition, it will require repeated cycles of shared professional development to help teachers keep pace with advances in technology and new research. As challenging as this path may seem, it is attainable, and by the best information available, it is also the most efficient and effective means to achieve technologically proficient teaching and learning.

In the *Learning Tomorrow* program, an NFIE technology grant program targeted to students at risk of school failure, the more successful projects followed up professional development activities with continuing consultation with teachers in their classrooms (Hawkins, Baker, and Justin 1998).

Several *Road Ahead* sites set aside significant blocks of time over a period of months or even the entire school year for regular, sustained professional development. (How they managed to find the time is discussed later in this report.)

At Bijou Community School in South Lake Tahoe, California, for example, teachers participated in two hours of professional development one day a week.

Positive results

In the Phoenix *Road Ahead* project, the team devoted the entire first year to intensive professional development on technology integration. In the second year, two teachers were given release time for the whole school year to lead eight-week, one-hour classes for their colleagues on a variety of technology-related issues. The sessions were often well attended, and after a year of professional development, 60 percent of participants rated themselves as competent or proficient users of computers. The school also reserved one of its computer labs for teacher development for one whole day each week so those teachers could visit it during planning periods. Teachers also had remote access from home (Moursund et al. 1997-98). The school now has a grant to expand its professional development model to other schools in the district.

It also takes a critical mass of teachers to bring about fundamental change. Many *Road Ahead* sites made professional development available to the entire teaching staff and sometimes to support staff, student teachers, and community members as well. The project at Lakeside Elementary in Manistique, Minnesota, for example, provided technology-related professional development to all the teachers in the school. This created a sizable group of teachers proficient with technology and helped to diminish resentments that can arise when special programs are available only to a select group of teachers.

Realistic and Visionary

Rather than presenting abstract concepts, high-quality professional development addresses the real issues that teachers face in using technology in their classrooms. Many effective programs set teachers to work on solving authentic problems that are relevant to their subject matter or grade level. Relevant professional development also means that teachers use the same tools their students use. Teachers utilize technology applications in much the same ways as they expect their students to do.

Linking technology to practical and immediate goals and to broader reforms

Being based in reality need not mean a loss of vision. Technology-related professional development is most effective when it is not singled out as an end in itself. The best results are achieved when it is an aspect of a clearly articulated vision for school reform, and also when it is closely tied to district or school improvement goals. In both the *Learning Tomorrow* and *The Road Ahead* programs, the most successful projects prepared teachers to use technology in ways that were practical and immediate but were also linked to broader reforms.

In the *Learning Tomorrow* program, the most extensive changes occurred in sites that helped teachers adapt technology to local reforms, rather than just teaching them the raw applications of various software (Hawkins, Baker, and Justin 1998). All of *The Road Ahead* projects had specific improvement goals for their schools—from improving reading comprehension to finding better ways to teach science. Some, however, were more closely linked than others to the district's vision for comprehensive school reform.

Building a Collegial Professional Culture

Working together to learn technology and to teach other colleagues

Many effective strategies for professional development have a common goal of building a collegial and collaborative culture of teaching professionals. Collegial communities share certain characteristics: all the professional staff work toward common goals; they participate together in high-quality professional development; they share ideas and knowledge; they publicly recognize good ideas and accomplishments; and they provide constructive criticism and encouragement to their peers.

The members of such learning communities share values and facilitate continuous learning. The goal is to create a climate where systemic improvement can take hold, even as individuals are improving their own skills and knowledge. Becker and Riel (1999) found that the more teachers were engaged in collaborative work within and beyond their schools, the more likely they were to report using instructional practices that emphasized deep thinking and project-based learning.

This type of culture takes time to build. People need to reach a point where they trust each other, recognize the specific strengths that each team member can contribute, and become accustomed to peer assistance and constructive criticism. Just as in other workplaces, teachers have different levels of comfort with and expertise in technology. They must learn to work with colleagues of different skill levels.

Many effective professional development efforts extend their models of collaborative communities to include people other than teachers, such as school administrators, support staff, representatives of after-school programs, and representatives of community-based organizations. They also bring outside expertise from universities, museums, and other cultural resource institutions into the mix as appropriate. Effective collegial teams are composed of people who share mutual benefit from the collaboration.

Students and teachers learning together

Some projects also experimented successfully with the idea of having students learn alongside teachers. In *The Road Ahead* project in Renton, Washington, for example, teachers were asked to bring along a student to their learning sessions. Often students were more technologically adept than teachers and could give teachers valuable input about using new software. This helped teachers get used to the idea that it was all right to learn from their students. The students, for their part, received positive reinforcement of their knowledge and were exposed to a model of lifelong learning. After the learning sessions, students served as classroom assistants for information technologies.

Everyone may have brought different strengths and knowledge, but everyone gained valuable knowledge from this mutually beneficial model of professional development. Renton's approach to professional development had the additional benefit of preparing students for the modern workplace, where people of diverse ages, skills, and backgrounds must work together in collaborative teams.

Professional Development Strategies for Improving Technology Skills and Knowledge

Professional development can take many different forms and use a variety of strategies. The short-term and long-term goals of the teachers and the school determine the specific professional development strategy.

For example, if the short-term goal is to acquaint teachers with the Internet—what it is and how to access it—then a workshop may be an appropriate starting point. If the long-term goal is to help them use the Internet to change their teaching practices, then a combination of more intensive strategies will be required.

Described below are some of the most common forms of professional development that have been effective in developing knowledge and skills related to technology.

Conferences, Institutes, Workshops

Although the field is moving far beyond the idea of one-shot workshops, shorter-term conferences or workshops can still have a place in professional development. They are often useful to introduce a topic or provide information on specific skills that can be linked to more sustained forms of professional development at the school site.

Effective use of traditional models

The annual summer conferences of the *Road Ahead* program provided an opportunity for project teams to learn in a structured way from others with expertise. It also provided a venue for them to meet with their electronic mentors face-to-face, to interact with people from other sites, and to meet with project evaluators. The conferences were designed to expose the teams to ideas that could inform more sustained professional development efforts back in their districts.

Courses and Classes

Formal courses and classes are another traditional approach that continues to have a place in technology-related professional development. In the Columbia, South Carolina, *Road Ahead* project, a graduate class at the school site had a major impact. Teachers began implementing what they were learning while the class was still underway, and they continued their collaboration and professional development after it was over. As an extension of the initiative, the university chose the school to become a professional development school for its teacher preparation program.

Action Research and Study Groups

Action research is a process that encourages teachers to systematically study what they do as a way of improving their practice. As described by Susan Loucks-Horsley and her colleagues (1998), teachers examine their own teaching and their students' learning by writing descriptive reports about classroom processes, by engaging in meaningful conversations, by reflecting critically about their own practice, and by sharing their findings with their colleagues.

Additional effective approaches

The underlying message communicated through these reports is that teachers are intelligent, inquiring professionals with valuable practical experiences and problem-solving skills. They can advance professional knowledge just as much as scholars do through empirical studies.

Action research: teachers may develop their own research designs

In action research, groups of teachers define—or play a meaningful role in defining—a key research question that would help them improve practice, such as whether they treat boys differently than girls in access to classroom computers. After reading up on the research on this issue, teachers might develop their own research design. The design may include such data-gathering elements as keeping logs of which students used the computers and for which tasks, audio taping their classes to see how they respond to students' requests for computer time, and observing each others' teaching. Together, these teachers might then review the data, analyze their findings, come up with a strategy to address any problems, and share their recommendations with other faculty.

Study groups: together, teachers examine a substantive issue

Study groups bring together teachers to study a substantive issue they care about—for example, how to assess students' understanding of key concepts in a project-based science curriculum. Groups meet regularly to discuss, share, analyze, reflect on, and ask questions about various approaches they are using or would like to use (Loucks-Horsley et al. 1998). Individual group members may assume responsibility for collecting information and keeping abreast of research on one or two aspects of the issue chosen, so that each person develops a particular expertise that can be shared. Teachers who become well versed in those particular aspects then have a responsibility to help colleagues improve their capabilities.

Both action research and study groups motivate teachers to examine their basic beliefs, often motivating them to modify or replace those beliefs with others that are grounded in research and good practice. These forms of professional development can enhance a teacher's sense of professionalism and can also create a climate where people are comfortable with openly discussing their practices.

Mentoring

Mentoring pairs teachers who have experience in a particular skill or area with one or more teachers who can benefit from their expertise. It was a key professional development strategy in *The Road Ahead* program. For mentoring to be effective, the creation of mentoring teams requires careful matching; the teams should be designated rather than created by informal pairing.

Characteristics of effective mentoring

Mentors can provide advice, reassurance, encouragement, and technical assistance. They can serve as a sounding board for new ideas and give objective critiques of plans or ideas. Some of *The Road Ahead* mentors also gave workshops at project sites or arranged for other kinds of professional development, and a few even intervened on behalf of their site team to solve problems within the district (Moursund et al. 1997).

It is important to choose mentors who will be a good fit for the individual or group of protegés in terms of interests, goals, and skills and who have knowledge and time they can and will devote to the relationship. For the relationship to work, the people being mentored must be willing to accept outside help. Furthermore, mentors cannot be expected to take on these responsibilities without incentives—recognition, some type of compensation, professional development for the mentoring role, and (a critically important component) time.

Benefits of mentoring

The mentoring relationship brings benefits both to those being mentored and to the mentors themselves. According to a 1998 U.S. Department of Education survey, 70 percent of teachers who were mentored at least once a week said it improved their teaching "a lot" (U.S. Department of Education 1999). Mentors grow professionally, too, by reflecting on what they know, distilling it into an accessible form, and carrying out new leadership roles.

Mentors can be located at the site or connected by technology. The *Road Ahead* project used long-distance mentors who communicated with their teams by email and telephone (which is preferable for sensitive discussions). The mentors also met face-to-face with their teams at the summer conferences, and several made site visits to schools. When mentoring relationships depend upon long-distance communications such as email and written correspondence, occasional high-quality, face-to-face meetings are vital to the success of the mentoring experience. These meetings create a feeling of trust and facilitate the critiquing of project plans. Such activities are better accomplished around a table and give validation to both the mentor and the project (Moursund et al. 1997).

Models of mentoring

Although the mentors in *The Road Ahead* kept in fairly frequent contact with their sites, especially during the first year, the quality of contact appeared to be more important than the frequency. Some mentors felt underused and wanted clarification of their purpose. In response NFIE asked project mentors to play a greater role in planning the 1997 summer conference, which turned out to be the most highly rated of all the conferences. The mentors did much of the planning online with selected team members. They also facilitated most sessions and handled many of the logistics.

This model, which entrusted mentors with elements of program leadership and engaged them as teachers as well as advisers, had much to recommend it. It took better advantage of highly skilled people and allowed more people to benefit from the collective skills of all the mentors, rather than just from a single mentor assigned to a specific team (Moursund et al. 1997).

Teacher Networks and Online Communities

Networks of teachers who come together for learning, sharing, and support can be either local or electronic. Each has its advantages. Electronic networks can break down barriers of position and status that might inhibit face-to-face interactions. They also give teachers an opportunity to model the kinds of online networking they expect their students to do.

Characteristics of successful online mentoring

Successful online communities for professional development are ones that communicate regularly, use the medium to solve problems and advance their work, and persist after the initial reason for coming together is over. A review of electronic networking among *Road Ahead* project teams found that some of the sites were very active users, and others were very infrequent users. The most active individuals were the team leaders and mentors. Often the communications were about the projects or the mentoring process, but just as often they were informal and not related to the projects. *The Road Ahead* experience suggests organizing electronic forums topically rather than by site, creating temporary strands around topics of interest, and appointing a moderator or facilitator for online projects (Underwood and Bielefeldt 1996).

The development of online communities will continue to benefit from increases in bandwidth and improvements in networking software. Technical difficulties, concerns about privacy, and a confusing or overwhelming interface can discourage participation by all but the most intrepid.

Participation in online networks must come to be seen as a valuable collegial work activity, not an extra or add-on. To achieve this status the networks must be able to show links between their activity and tangible learning results for participants and their students. Researchers can help by conducting more studies of electronic communities to determine the most effective structure, support, and content. Administrators can demonstrably support the value of online learning environments by making time for teachers to participate in them.

Professional Development Embedded in Other Responsibilities

Professional development occurring through other activities

Teachers are learning and expanding their skills as educators even as they go about parts of their job not overtly labeled as professional development. Assessing students is one example. When assessment results show that students need to improve in a particular area, it causes teachers to examine their practice and consider ways to make it more effective. In *The Road Ahead*, the national evaluation of the program (ISTE 1998) became a form of professional development for teachers by providing formative information that helped the sites improve their programs.

Strategic planning is another example. When teachers are involved in developing a technology plan, they must learn more about various options for hardware and software and think about how they would use them. They must also weigh their own needs against those of a broader set of schools and place their priorities for technology integration within the wider context of school improvement planning.

Support, Access, and Structures for Technology-Related Professional Development

The effectiveness of professional development is shaped by many factors in the larger context. Having in place certain kinds of structures and services can make it easier to expand successful professional development efforts to a larger scale and can help to sustain them over time. Research from NFIE and others (NFIE 1996; Parsons 1998a; Parsons 1998b; Loucks-Horsley et al. 1998) has identified some of the most important supports, which are described below.

Time

As noted already, it takes time for teachers to learn how to integrate technology. Lack of time and scheduling problems were frequently mentioned as impediments by *The Road Ahead* sites (ISTE 1998). Nevertheless, some teachers and administrators figured out innovative ways to create more time for professional development.

Adequate time and flexible scheduling enhance professional development

In Union City, California, the district obtained a waiver from the state that allowed it to delay the students' starting time every Wednesday to give teachers an extended block of time for professional development. Many teachers felt that what the students gained from being taught by better prepared teachers more than offset the loss of instructional time. Bijou Community School in South Lake Tahoe also delayed its starting time one day a week, but this school did so by extending the school day by 15 minutes for the four other days and by pooling contractual preparation time. Lakeside Elementary, in Manistique, Minnesota, reserved a half-day for technology-related professional development every three weeks; this school used substitutes to cover for teachers.

These are just some of the options available for creating more blocks of time for teacher growth. Among the others are pooling of early release time, team teaching, eliminating unnecessary meetings and administrative tasks, reorganizing teachers' individual preparation time to allow more common time together, and extending the school day (Loucks-Horsley et al. 1998).

Access to Equipment and Technical Support

Ready access to technology equipment by well-trained teachers is necessary

Although access to sufficient hardware and software seems like an obvious prerequisite for technology-related professional development, access remains a problem in many schools and districts. In some cases, there is not enough equipment. A teacher with one computer in the classroom and no Internet access or projection equipment cannot implement some of the more exciting possibilities for technology-based instruction. Almost half of *The Road Ahead* sites were hindered by problems relating to access to technology, such as insufficient computers, computers tied up for administrative tasks, problems with donated equipment, lack of connectivity, and unreliable network access.

In some instances, the technology is there, but may be distributed in an inefficient and inconvenient way. For example, all technology may be concentrated in a technology lab and not in the classrooms. Such restricted access limits serendipitous learning, where teachers and students can capitalize on loosely structured opportunities that arise and could be enhanced by the use of the Internet.

A related issue is the degree of synchronicity between technology acquisition and professional development. A general rule of thumb is that teachers should do their professional development on the hardware and software that is actually installed in the school as soon as it is installed, with repeated sessions for new staff or as new hardware and software are added.

Access to on-demand, onsite technical assistance is another necessary support. Some schools rely on the district to provide this support, while others provide their own. *The Road Ahead* project in Union City, California, gave release time to a media specialist to help teachers with technology integration—a level of coordination that was made easier because the district had in a place a technology plan.

Strategic Planning

Professional development tends to be more effective, substantive, and long-lived when it is aligned with or built into a school's or district's strategic plan. This plan should be created with meaningful involvement of teachers. It should also give teachers a continued role in decision-making. Some of the most effective *Road Ahead* projects had in place district-wide technology plans that included professional development as a critical element.

Working on a strategic plan can itself be a valuable form of professional learning for teachers. Strategic planning can help participants to remain focused on the school's or district's broad goals for educational reform. Technology can sometimes command undue attention, causing teachers to lose sight of their role in facilitating subject matter learning and student learning goals. Participating in strategic planning can help teachers put learning, not technology, first.

Professional development best when built into strategic planning

An Openness to New Teacher Roles

High-quality professional development often encourages teachers to assume new roles—as mentors or coaches, as teacher leaders or teacher trainers, as technology coordinators—but teachers will be less effective in these roles without certain kinds of support from the school or district.

An openness to new forms of teacher leadership is one such support. In districts with an authoritative or centralized approach to leadership, some of the types of collaborative or decentralized leadership encouraged by professional development could be viewed as a threat and could fail to thrive unless care is taken (Parsons 1998a).

Incentives for teachers to learn and teach new skills and assume new roles are another form of support. Teachers cannot indefinitely keep up the levels of energy that several put forth to make a special program like *The Road Ahead* work. Examples of effective rewards include not only cash stipends but also release time and formal recognition of achievement.

Leadership

Supportive leadership from the district level is another critical factor for technology-related professional development. A district's formal commitment to technology can create a climate where professional development will flourish. A superintendent or other influential leader with a vision for technology-based systemic change can take such vital steps as reallocating staff time, improving access to technology, revamping schedules, or encouraging coordination. *The Road Ahead* projects tried to instill support among school leaders by including administrators on local project teams.

Organizational and administrative support

Superintendents and principals are not the only ones who can exercise leadership for professional development. Professional teacher associations can provide leadership and encouragement and can put in place conditions that will help to ensure that supportive structures live on when district leadership changes. Teacher associations can help establish these conditions and structures by negotiating with local districts, influencing state policy, engaging the community, and establishing teacher centers (Parsons 1998a). External groups like NFIE can help sites enhance the quality of their professional development and can make suggestions for designing programs and influencing policies.

State and Local Policies

State and local policies are a powerful force that can support or impede professional development. Particularly salient are state policies regarding curriculum and content standards, assessment, school finance, professional development, strategic planning, teacher preparation, licensure, certification, and evaluation (Parsons 1998a). Also relevant are such local policies as professional development priorities, teacher time and roles, and site-based decision-making. Supportive policies can initiate a philosophical shift that results in change.

Supportive policies can result in high-quality professional development

Even if these policies are not in place, the situation is not hopeless. Sometimes the policies follow after local actions prove to be successful.

Teachers are feeling a major impact from the state policies to adopt content and performance standards for student learning, along with high-stakes accountability measures based on those standards. Standards can affect the priorities for professional development by delineating what students need to learn and teachers need to teach.

Pressure to improve student achievement rapidly on standards-based assessments can drive the curriculum in ways that may or may not appear to be consistent with the goals of technology-based teaching and learning. Integration of technology that puts content learning objectives first and lets curriculum drive the use of hardware and software is most likely to be compatible with standards-based learning.

Emphasizing content learning objectives is compatible with standards-based learning

Community and Parent Support

Support for professional development can come from community agencies and organizations, museums, libraries, businesses, higher education institutions, and other local partners. It helps to have formal policies to lay the foundation for collaboration.

Parents and public informed about value of professional development

The Road Ahead projects required community representation on project teams. Among the partners selected were museums, community agencies, laboratories, and universities. These partners provided sites and resources for professional development and also participated in it. Several community members greatly appreciated these professional development opportunities, which are far more rare in the community-based sector than in schools. These forms of collaboration also helped to generate a community buy-in for the changes occurring. At Page Middle School in Franklin, Tennessee, teachers and other team members said that the collaborative strategy had created "circles of support" for technology comprised of teachers, parents, and community members (Moursund et al. 1997-98).

It is critical that parents, as well as the larger public, understand the necessity of high-quality professional development. Parents and the public should be informed about issues such as why teachers need to spend time outside the classroom on professional development, why technology implementation requires an extensive level of professional development, and what high-quality professional development looks like (Parsons 1998a).

A lack of understanding about these issues can be a real impediment. Educators must take the time to explain the dimensions and benefits of professional development in terms that make sense to parents and other citizens. School-business partnerships can help the public to understand the changing nature of knowledge workers' jobs. School-business partnerships can also educate parents and the public about how the job of today's teacher has significantly changed over the past several decades, thus widening recognition of the need for continuous and well-supported teacher learning.

Adequate Funding

High-quality, sustained professional development costs money. Often schools or districts rely on special funding sources, such as state, federal, or foundation grant programs, rather than district sources; however, this strategy runs the risk of having the reforms disappear with the external funding. It is important to institutionalize professional development with local contributions, which may include in-kind support.

In general, it makes sense to reserve a significant portion of general technology acquisition funding for professional development. Existing professional development funds may need to be refocused on the most effective strategies.

Assessing the Effectiveness of Professional Development

Gauging the effectiveness of professional development in technology applications

How do teachers know whether professional development is working? Are they teaching in new ways that improve the learning experience for students? One way to evaluate the effectiveness of professional development is to measure changes in what teachers do in the classroom.

Many assessments rely on the teachers themselves to report the extent to which programs have changed their practice. This is one useful source of information, but it can be augmented by external assessments, such as classroom observations, interviews, analyses of lesson plans and other products, performance tasks, and focus groups. Projects do not necessarily have to create their own evaluation instruments from scratch, but can use or adapt those produced by groups experienced in evaluating professional development (Loucks-Horsley et al. 1998).

A second measure, and a more elusive one, is a change in student achievement. Because achievement is affected by many factors, it is more difficult to attribute improvements specifically to professional development. Nevertheless, there is some research indicating that high-quality professional development has a positive impact on student achievement.

Cohen and Hill (1998) found that certain kinds of teacher professional development affected teacher practice, which in turn made a positive difference in students' mathematics achievements. The critical elements were that the professional development was grounded in the specific curriculum the students were studying, that it was aligned with assessment and other elements of instruction, and that it was extended in time.

In fourth-grade classrooms where teachers reported classroom practices more oriented to the curricular framework, students had higher achievement scores. No such relationship was found in schools where teachers used conventional practices or where professional development focused on special topics. These findings emphasize the importance of aligning professional development with what students are expected to know.

A third type of measure relates to systemic changes in the school environment. Examples include changes in the amount and types of collaboration, in leadership and decision-making authority, in policy, and in planning (Parsons 1998b).

The Promise of Technology for Improving Professional Development

As the above discussion illustrates, technology can change the process of professional development as well as the content. Information technologies open up new ways of conducting and participating in professional development.

Technology uses in professional development

For example, teachers can learn new skills by video taping classrooms in action. They can acquire new information by connecting with online experts and databases. In addition, technology can link teachers with distant learning opportunities and create professional learning communities not bound by location. Technology also allows teachers to work either individually or collaboratively.

Technology can help to embed professional learning opportunities into teachers' everyday responsibilities. Many technology-supported learning resources are available at any time and can be called up when needed.

Finally, projects that start by focusing on technology can end up leveraging greater support for professional development in general (Parsons 1998b). Successful models of technology-based professional development can be applied to teaching and learning in other areas.

It is an exhilarating time for technology in schools, in large part because technology can stimulate opportunities for life-long, job-embedded professional development that significantly increases how well we prepare students to meet the world of the twenty-first century.

"Professional Development and Information Technologies" is one of several papers included in *Connecting the Bits, A reference for using technology in teaching and learning in K–12 schools*, issued by the National Foundation for the Improvement of Education in 2000, and available at www.nfie.org.

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This paper examines the relationships among teachers' role orientation, the school culture they experience, and their personal teaching practices using information from a national sample of 4,000 teachers across 1,100 schools, including schools involved in major reform programs. The findings suggest that teachers who are engaged in collaborative professional activities extending beyond their classrooms are more likely to have their students work in collaborative ways as well.

Cohen, D. K. and H. C. Hill. Jan. 1998. State policy and classroom performance: Mathematics reform in California. *CPRE Policy Briefs.*

This report presents findings from a survey of California elementary school teachers on the classroom effects of state efforts to reform mathematics teaching and learning. The report focuses on findings related to three main questions: What learning opportunities were available to teachers and others responsible for implementing the new Mathematics Framework? What mathematics content and pedagogies were teachers taught? Was there any connection between teachers' learning opportunities and practices?

Hawkins, J., T. Baker, and G. Justin. 1998. The Learning Tomorrow Project: Final assessment report. Paper prepared for the National Foundation for the Improvement of Education. New York: EDC Center for Children and Technology.

This final assessment of the *Learning Tomorrow* program reviews the technology integration activities of ten sites; the logistical, professional development, and planning support infrastructure provided to the sites; and the assessment activities of the sites. The analysis focuses on issues of leadership, infrastructure building and operation, curriculum and pedagogic goal development, community building and interaction, strategies for school change related to technologies, and school policy changes required for technology integration.

International Society for Technology in Education. 1998. The Road Ahead evaluation. Report submitted to the National Foundation for the Improvement of Education. Eugene, Ore.: ISTE.

The document summarizes *The Road Ahead* program and describes methodology. The report examines student learning, professional development, technology use, systemic change, factors that helped and hindered programs, and program support. Recommendations, a bibliography, and an appendix are included. Available on NFIE's web site, www.nfie.org.

Lewis, L., B. Parsad, N. Carey, N. Bartfai, E. Farris, and B. Smerdon. 1999a. Teacher quality: A report on the preparation and qualifications of public school teachers. *Education Statistics Quarterly* 1(1): 7-11.

This report focuses on teachers' preservice qualifications, continued learning, and workplace support. It examines and provides a context for teachers' feelings of preparedness to meet new challenges posed by education reforms, technological changes, and increased student diversity.

———. 1999b. *Teacher quality: A report on the preparation and qualifications of public school teachers. Statistical analysis report*. Washington, D.C.: National Center for Education Statistics.

This report is based on efforts by the National Center for Education Statistics to collect data on teacher preparation and qualifications using a nationally representative survey of full-time public school teachers. The report includes indicators of preservice and continued learning, and examines work environments in which educators teach. It discusses how teacher quality has been defined and studied, preservice learning and teaching assignment, continued learning, supportive work environments, and teachers' feelings of preparedness.

Loucks-Horsley, S., P. W. Hewson, N. Love, and K. E. Stiles. 1998. *Designing professional development for teachers of science and mathematics*. Thousand Oaks, Calif.: Corwin Press.

This comprehensive guide discusses how to design staff development in science and math. It is tailored specifically to the needs of individual schools or departments. The book provides fifteen strategies for professional development and describes each one with its underlying assumptions and implementation requirements. Vignettes from real schools illustrate concepts within the book.

Moursund, D. and T. Bielefeldt. 1998. Computer technology and professional development: Suggestions for schools. Paper prepared for *The Road Ahead* program. Eugene, Ore.: ISTE.

This report examines the professional development challenge in information technology. After listing a number of professional development challenges, it discusses three approaches of staff development that can help meet the challenges. The report provides an outline of an effective model for staff development for technology in education.

Moursund, D., T. Bielefeldt, S. Underwood, and D. Underwood. 1997-98. Site reports on individual projects funded through The Road Ahead. Prepared for the National Foundation for the Improvement of Education. Eugene, Ore.: ISTE.

These documents provide project summaries and evaluations for the twenty-two *Road Ahead* sites. Included in each site report are an overview, goals, outcomes, and the project's future plans. The site reports are available on NFIE's web site, www.nfie.org. Also located on the web site are links to each site's project and team, site evaluation, and web sites created by the students participating in the program.

———. 1997. Mentoring on The Road Ahead. Paper prepared for the National Foundation for the Improvement of Education. Eugene, Ore.: ISTE.

This report discusses the role of team mentors in *The Road Ahead* program. The mentors helped teams revise proposals and develop workable plans that met the requirements for the grant and provided ongoing technical assistance to the teams as needed. The report presents findings from surveys and interviews of mentors focusing on how the mentors assisted their teams, what the mentors got out of the experience, and the effectiveness of mentoring at a distance.

National Commission on Teaching and America's Future. 1996. *What matters most: Teaching and America's future.* New York: NCTAF.

The premises of this two-year study are: (1) what teachers know and can do is the most important influence on what students learn; (2) recruiting, preparing, and retaining good teachers is the central strategy for improving our schools; and (3) school reform cannot succeed unless it focuses on creating conditions in which teachers can teach and teach well. This report focuses on perceived barriers to achieving these goals and offers five major recommendations: get serious about standards for both students and teachers; reinvent teacher preparation and professional development; fix teacher recruitment and put qualified teachers in every classroom; encourage and reward teacher knowledge and skill; and create schools that are organized for student and teacher success.

National Foundation for the Improvement of Education. 1999. *Creating a teacher mentoring program.* Washington, D.C.: NFIE.

This issue brief provides guiding principles for structuring a mentoring program based on tested findings in schools and school districts throughout the country. Topics include ensuring time for mentoring, maintaining confidentiality, selecting and training mentors, measuring results, and establishing partnerships among educational organizations and associations. Available on NFIE's web site, www.nfie.org. A list of resources and key questions is included.

———. 1996. *Teachers take charge of their learning: Transforming professional development for student success.* Washington, D.C.: NFIE.

This report explores the conditions and policies needed to incorporate teachers' learning into their daily work in the schools. It identifies the incentives, processes, policies, and structures that support wise, shared decisions about teachers' own learning and that of their colleagues so that they will be better able to serve their students. Findings from this study indicate that providing for effective professional development requires: (1) flexible scheduling, (2) extended school year for teachers, (3) school-based professional development, (4) standards and accountability, (5) balancing individual teachers' and school needs for learning, (6) peer assistance and review, (7) expanded role for teachers, and (8) induction of teachers.

Parsons, B. A. et al. 1998a. Historical patterns and trends impacting professional development: Case studies of four districts in A Change of Course. Paper prepared for the National Foundation for the Improvement of Education. Ft. Collins, Colo.: InSites.

Through four in-depth case studies, this report looks at how historical trends and patterns impact the process of change as school systems seek to achieve sustained high-quality professional development for all teachers. Using a theory of change, the report analyzes the patterns of factors influencing professional development in each site. The report concludes by addressing consideration for the sites and how external organizations can support the education system at local, state, and national levels to achieve the goal of sustained, high-quality professional development for all teachers.

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The results of this national profile of teacher quality, the first in a series of biennial reports, includes information on teachers' education, certification, teaching assignments, professional development, collaboration, and supportive work environment. The report provides a context for understanding teachers' reports of preparedness to meet the challenges they face in their classrooms.

At-Risk Students: Technology's Particular Promise

Introduction

Since the introduction of chip-based technology into classrooms in the early 1980s, educators have sought to learn how this extraordinary resource could benefit students at risk for school failure. Many teachers and some researchers feared that attempting to use technology in teaching might place these children, who face many challenges to the mastery of academic skills, further behind.

More than a decade of research, development, and implementation make it clear that the reverse is true—integrating technology into the curriculum properly can produce dramatic change and improved prospects for at-risk students. The change can also be measured in classrooms transformed from places that many students wish to avoid to places where students are eager to work. The change can be measured in students who have altered their life course to become enthusiastic learners moving toward positive academic and career goals.

Change comes about in part because effective use of technology for teaching dissolves many barriers and alters traditional methods and attitudes. New strategies are created. Successful technology integration involves complex sets of factors including, at a minimum, commitment to changing curriculum, high-quality professional development, flexible scheduling and instructional management, and a shift from rote learning to project-based learning.

Change means new attitudes and new roles for teachers and students. It means a shift from learning aimed at raising scores on high-stakes tests to learning that emphasizes intellectual achievement through problem solving and teamwork. Change puts students at the center of their own learning.

This paper discusses

- a new learning environment;
- technology-based teaching and project-based learning
- family and community involvement;
- assessment through technology-based learning;
- an annotated bibliography

Holding the course can transform schools

In these transformed schools, technology acts as a powerful change agent, not simply as one more resource. A school that is able to hold the course can transform itself and reshape the lives of students with technology. Conversely, a school that is unable to change will waste even a substantial investment in modern hardware and software.

Technology is not a panacea for any student. At-risk students underachieve in literacy and numeracy skills from the early grades, have not been exposed to the same cultural opportunities out of school as their affluent peers, and are often bored or indifferent to education. These problems are not overcome easily or quickly.

Challenges with at-risk students

In addition, many schools serving these populations are themselves burdened. They are often characterized by teachers with little control over curriculum content or class scheduling, uncertified personnel or teachers with class assignments out of field, inadequate materials and supplies, excessive paperwork demands, and inadequate leadership at the building or district level. Thus, the school itself becomes one more obstacle for students most in need of help.

In 1994 the National Foundation for the Improvement of Education (NFIE) launched a three-year national initiative, the *Learning Tomorrow* program, with financial assistance provided by Sega Foundation of America and AT&T Foundation. This program supported teams of teachers and administrators at ten schools as they designed, developed, and implemented efforts to integrate technology into the curriculum and meet the unique learning needs of their students. The lessons of *Learning Tomorrow* reinforce findings of researchers examining the interaction of technology in school environments.

This paper discusses technology's contributions to improved learning with at-risk students, including characteristics of successful programs. Examples from Learning Tomorrow sites and other programs describe how teams constructed and implemented their approaches.

A New Learning Environment

Several factors must be in alignment for the power of technology to be realized with at-risk students. These factors include leadership; teachers working as an effective team; high expectations for students complemented by the necessary academic support to meet challenging goals; well-designed and continuing professional development; and parental involvement and community support. All these elements contribute directly to new attitudes and new outcomes.

At the heart of the effort must be a shared vision of good education, a vision that is constructed by leaders, teachers, parents, and students together over time. Once this vision is firmly in place, a school or school district can achieve a turn-around. Lacking this component, placing technology into classrooms will likely have a useful but limited effect.

What are characteristics of a powerful vision of good education?

- **It defines all students as able to learn and achieve.**
- **It has strong academic goals for all students.**
- **It contains social goals for students that support academic achievement.**
- **It provides the scaffolding necessary for all students to reach high expectations.**
- **It strives to use educational technology in ways that cannot be replicated by traditional means.**
- **It is constructed by the people who will implement it—the administrators, teachers, students, and community.**
- **It includes for all faculty the job-embedded quest to identify and implement high quality teaching and school leadership.**
- **It is based on an underlying theory of education.**
- **It requires open and frequent communication with parents and other stakeholders and their involvement in issues of student learning.**
- **It includes high-quality professional development.**
- **It demonstrates how every job in the school contributes to student learning goals.**

- **It requires the use of results and experience to constantly adjust and improve the effort.**
- **It includes effective incentives and a system of individual and collective accountability for outcomes.**
- **It provides the opportunity for teachers to have the authority and power to make teaching and learning decisions.**
- **It requires that goals for student achievement drive the development of policies and practices, including scheduling, deployment of technology infrastructure, etc.**
- **It provides a method for renewing the shared vision.**

An example of such a vision is the following goal of the *Learning Tomorrow* site at the Area Learning Center in St. Cloud, Minnesota:

> To create a technology-infused learning environment where at-risk students become motivated, self-directed learners who can work collaboratively through various technologies as evidenced by attendance and completion of meaningful academic performance and multimedia tasks that reflect higher-level thinking processes

Established goals

The *Learning Tomorrow* experience underscores that success is directly linked to a school district leadership whose established goals and purposes for the use of technology go well beyond simple acquisition of hardware. A critical mass of people in the district must have a coherent and shared view of good education, and skilled teachers and building administrators must have the responsibility and authority to implement the vision. Shared vision is also a prerequisite for giving a new approach enough time to be tested, implemented, fine-tuned, and improved. Three to five years is considered a realistic period for this level of change.

School team

The second component of effective change is leadership by a powerful school team. These educators have the intellectual, emotional, and physical stamina for long-term work with at-risk students, and for them this work is a priority and a pleasure. They create team approaches to provide support and reinforcement for each other and for students. This in turn increases the range of options for learning and supports many styles of learning. It also models teamwork—a capability their students need to acquire.

Good teams have complementary skills and backgrounds and include administrators and staff as well as teachers. Some *Learning Tomorrow* teams deliberately chose to divide their areas of technical mastery so that they all needed each other to organize and implement their courses and projects. This approach ensures that skills are complementary and there is no "star" teacher who is the most equal among partners.

Adequate time

As is always the case when substantial change takes place in schools, the level of effort and the amount of time the teams gave were extraordinary. It was not unusual for these teams to double the number of hours of the paid workweek. Several *Learning Tomorrow* teams were encouraged by NFIE to reduce the number of hours. Their commitment was total, but their risk of burnout was high. These teams made possible the development of engaging, stimulating, and productive instructional strategies. These programs went well beyond the basics, and they showed strong results in positive student performance and achievement.

Such promising results were achieved at Wilson Area Learning Center in St. Cloud, Minnesota. The pilot project at the Wilson Area Learning Center was designed to provide high-quality education for at-risk students in the St. Cloud school system. The Learning Center is an alternative school located in a building with two other alternative programs.

In contrast to the other programs, which aimed to return students to mainstream classrooms as soon as possible, the pilot project had a different objective. The team and the school principal wanted the pilot project to provide a permanent home by meeting all the academic and counseling needs of students. The theory was that returning students to regular classrooms was returning them to an environment of failure.

The team developed a thematic, technology-based framework for connecting students' learning through real-life experiences, collaboration, and critical thinking. Working in triads, students designed and completed projects using computers, video, CD-ROMs and other interactive technologies. The projects were also designed to prepare students for the workplace and involved research on careers, interviews with professionals, and presentation of information.

As the year progressed, teachers moved from units that were highly teacher-directed to student-driven units. Much of their material was biographical and focused on their personal and educational experiences. Students traveled to other alternative schools to train students and teachers in using technology.

To give the students total acceptance and support, the teaching team devoted tremendous time and energy to their work. They met three times a week: once to talk about every student, once to plan new themes, and once to prepare reports on each student. A mathematics teacher from another school joined the project to be able to teach mathematics thematically, an approach she had been told was impossible in mainstream schools.

The team members became frequent trainers of teachers in other schools. The principal gave total support to the pilot project. He helped resolve conflicts with other faculty and some members of the school board who were critical, at least in part because resources were being devoted to students who did not show promise in traditional ways.

Assessment was a major part of the pilot project. Diagnostic instruments such as the Meyers Briggs Personality Assessment and the Gregoric Learning Styles Inventory were used to create a baseline, and portfolio archives of student presentations and performance served as a major assessment tool in the four core subjects of language arts, employment skills, social studies, and mathematics.

At the completion of the pilot project, the principal and the team reorganized the school building, sending other programs to different sites, and developed a middle school and high school version of the *Learning Tomorrow* effort.

The success of Wilson Area Learning Center's pilot project is largely attributable to a shared vision. When the vision is clear, an atmosphere is created that offsets a factor that often destabilizes technology-based reform efforts—staff turnover. If a project is built upon one or two people, not only is the effect reduced, but if a key person leaves, the entire project usually falters. This experience occurred in more than one *Learning Tomorrow* site, and has been documented elsewhere.

Dedicated teamwork and district support

Principals and lead teachers change schools or positions periodically, and a new principal or superintendent may not wish to inherit someone else's program or may have different ideas about teamwork and collaborative learning. When the entire system means business, however, a new person will join the team one way or another. This occurred at Willow Bend Elementary School in Rolling Meadows, Illinois, when a new superintendent tried to impose a set of top-down directives. The school team rallied support to convert the superintendent into a project advocate.

> Willow Bend's success with its *Learning Tomorrow* program attests to the strengths of dedicated teamwork backed by district support. Willow Bend entered the *Learning Tomorrow* program as a traditional school. It was known as the lowest-performing elementary school in the district with the highest transient student rate and the largest bilingual population. Thirty percent of the students lived in poverty and fourteen languages were spoken.
>
> Willow Bend was the last building to be renovated in the district and was able to choose a new pedagogical design. The school superintendent, who was largely responsible for the opportunity to create a vision, also enlisted a new, dynamic principal. The faculty and principal decided to make a commitment to technology as a change agent for their school. All teachers were given the choice of leaving the school as change began, and some did. The remaining, more cohesive team decided that each teacher would be a leader in his or her own right, and all would share skills. They knew the principal and the district would support them.

Through *Learning Tomorrow*, Willow Bend implemented distance learning projects. Classes used the Internet to link up with sister classes around the world. Partnerships with different cultures were designed to increase self-esteem and cultural pride. The team aggressively used technology, with special emphasis on language learning. Team members were also sensitive to the needs of parents and to their learning levels.

The team developed a new curriculum with multi-age grouping and a thematic approach. Computers, laser discs, CD-ROMs, multimedia presentations, videos, and the Internet were used daily by staff and students. *Learning Tomorrow* initially focused on K–2, but it was quickly expanded, and the techniques were shared throughout the school. The school district budgeted a half-million dollars to transform Willow Bend to a successful school. Willow Bend chose to allocate those funds to technology, providing each classroom with about a dozen computers and the school with a well-equiped video studio.

The hard-working team developed their own academic materials and adjusted lesson plans to support their goals. They also developed *Civic Beliefs*, a project to find and reward good behavior. Students who were discovered doing good deeds were videotaped and shown on the in-house newscast.

In two years, Willow Bend rose to the upper one-third of the district in reading and math scores and had a 95 percent attendance rate. Team members became technology leaders and trainers throughout the district. Willow Bend has now become the district site for professional development for technology integration.

The development of strong teams is not simple or easy. Teams beginning new technology programs may experience isolation based on professional jealousy, simple envy of their status, or their access to resources, especially when the shared vision is not sufficiently broad.

First step: voluntary use of technology

When a whole school shifts to a technology-integrated approach, it is important to make the use of technology voluntary at first and provide many opportunities for high-quality professional development. Teacher resistance sometimes reflects the way the new approach was presented and the way in which opportunities were given to the faculty to become part of the experiment.

The empowerment that technology provides to learners requires changes in pedagogy that some teachers resist. For example, they must work with students in a collegial manner. When teachers are reluctant to change, patience and peer-to-peer support is especially helpful.

To strengthen the team, high-quality professional development is essential. The strongest *Learning Tomorrow* sites allocated about 36 percent of funding for professional development, including costs of substitute staff. NFIE provided an additional nineteen hours of training.

Learning and working together

The best results came when teams, including administrators, learned and worked together. This meant intensive training with the technologies the team selected, followed by excellent ongoing peer coaching and support in the classroom and continuing access to new tools, guidance, and advice.

All the techniques of professional development were available in these projects: mentoring, specific training defined by the team, technical assistance, administrative and technical support from NFIE staff, collegial study based on examination of student work, classroom visitations to master teachers, strategies for documentation and assessment, electronic networking, and access to online courses and materials. All the techniques were needed.

Technology-Based Teaching and Project-Based Learning

Teachers are intensely aware that motivation and learning are not the same thing. For many at-risk students, however, recapturing their interest in school at all is a prerequisite to improving their learning. A repeat of the old experience will only reinforce old attitudes and responses.

Technology can change schools in several ways that immediately benefit these students. First, students are given access to modern products that are part of today's world of work and education. Second, the technology requires active involvement by the students. Working in teams on technology that includes interactive media and online research calls for the students to put an active curiosity and intelligence to work.

Technology is patient. Even the most dedicated and understanding teacher sometimes conveys disappointment or anger toward a student; the technology never does. It also allows for learning that is both private and anonymous. This means that a student can take as much time as needed, at whatever speed is appropriate, to cover a lesson or a concept. No matter how long it takes, the student is not publicly labeled slow. Additionally, with good quality software, a student can explore new approaches to learning and is not limited to following the patterns imposed by teachers or peers. This is especially important for students whose learning styles are non-traditional.

Project-based learning and authentic, real-world applications increased student motivation

Learning Tomorrow teachers found that increased attendance and a willingness to "stay with the learning" were among the first results from a shift to technology-integrated learning. Because the students wanted to be in school to use the technology, they allowed themselves to expand their access to learning materials.

Part of the transformation from passive to active learning depends upon the availability of rich sources of materials, varied sources of information, and flexible time in which to work with the materials. All these things come as part of the technology package. When used strategically, the Internet and World Wide Web provide depth, variety, and access to distant resources. They also provide flexible access to rich data fields. Graphics and publishing software put powerful presentational tools in the hands of students and teachers. The results for at-risk students are enhanced engagement and productivity on increasingly complex tasks, with the scaffolding to enable them to be successful.

As classroom emphasis shifts from the memorization of facts to include inquiry, research, analysis, and synthesis of data culminating in development of a presentation, the opportunities for student success increase. As teachers become coaches and advisers rather than lecturers and drill monitors, the students begin to experience the collegial "give and take" that is characteristic of advanced learning. When the projects are authentic, students invest in the quality of their work because it matters. Typically, *Learning Tomorrow* projects moved over time from teacher-directed activities to project-based learning, and student achievement began to take off as these changes occurred.

In project-based learning, results are complex. Thus, many styles of learning and approaches are useful, even necessary, to the final product. This type of work develops individual strengths of learning as well as collaborative skills. Using network access, students begin to take responsibility for organizing research, work in groups to critique and synthesize information, and develop strategies for presenting results. They internalize an approach to learning that is open-ended, and they grasp the possibility and importance of continuing revision and improvement. In addition, they see information and data as critical tools for drawing conclusions rather than as bits of isolated material to be memorized.

Open-ended learning approach

As project-based learning develops, the time constraints of the structured school day can become a barrier. Often at this point, faculty and students begin to alter rigid patterns of segmented teaching and move toward more flexible scheduling. Another outcome is that students, teachers, and parents begin to think about new ways to recognize, evaluate, and reward this type of learning.

The extraordinary capability of the technology to bring resources into the classroom becomes more apparent as project-based learning grows. A school without funds for microscopes, field trips, visiting experts, and extended learning communities can acquire resources that provide rich learning experiences through software and online access. Teachers who have worked for years without up-to-date textbooks or materials can direct students to primary sources and download excellent lesson plans and activities. Authoring software and other tools give teachers new ways to customize teaching. The world comes to the classroom.

The resources that technology brings to the classroom increase constantly. This is in part because the initial costs of technology continue to drop, the capacity of technology continues to increase, and several federal, state, and local programs are now available to help schools acquire technology and connect with the Internet. In addition, ever more sophisticated software makes it possible to share expensive resources. It is now common for students to participate in scientific data gathering and analysis using software; the school does not have to purchase and operate the delicate instruments that are required.

Team-driven learning

This type of classroom not only increases the educational achievement of students, but it also prepares students for the modern, team-driven world of work. Exchanging information and solving problems with people of different backgrounds and ages is excellent training for the twenty-first century workplace. In many schools, teachers and students learn together. Shaping a new learning sequence, devising new presentations for others and new initiatives for the classroom—all these activities are better done with contributions from everyone.

Family and Community Involvement

Educators have always understood that the school is only one of the formative factors in a child's education. Attitudes and opportunities within the family make the most difference, and resources in the community can also be enlisted to support educational achievement. Although less well documented than some other elements of at-risk programs, technology initiatives with families and communities present new avenues and tools.

Some projects have used technology well to achieve these goals. For example, Phantom Lake, in Bellevue, Washington, sent AlphaSmarts, portable word processing appliances, home with children whose first language was Spanish, so that parents could use the technology as well. This project eventually led to establishing a Mexican Club at school, which involved parents and celebrated their culture.

Technology can provide information to families about educational objectives and student progress. Technology can be used to find social and health resources to meet family needs. It can also be used directly by the family for their own educational and communications purposes. Well-designed efforts to send technology home with children or to open school facilities to families after school have succeeded.

Technology may strengthen ties in school, family, and community

In addition to providing access to services and materials, technology builds community between school and family in new ways. As access to the Internet expands, many schools have recruited community partners for special activities at schools, using email and online opportunities to bring resources to the school and export resources back to the community.

An NFIE project in Eau Claire, Wisconsin, linked elementary school children with a senior citizens center. Many of the children were of Hmong background and had a difficult time with English and with the culture of their new home. Many of the senior citizens had memories about the history of Eau Claire and the region that they wanted to share. Over time, via email and visits, a strong bond was established between the two groups, and the children became highly proficient at describing and demonstrating local history through hypermedia.

In a learning community, teacher/pupil lines blur

One area that has helped open schools to this approach is the installation, upgrading, and maintenance of the technology itself. Students are often better suited to these tasks than teachers and more available than technical support staff. Certification for students as technical assistance staff and technology instructors has become common. As this occurs, the relationship between the "teacher" and the "learner" inevitably shifts, and the students can become teachers for adults in the community as well as helpers for their peers in school. Everyone is a teacher and everyone is a learner. All gifts and talents are valuable in a true learning community.

Finally, winning the support of parents and community groups requires being able to explain the purpose, goals, and nature of technology integration in terms that are recognizable and clear. A phrase coined by Dennie Palmer Wolf articulates this point well: teachers and administrators must have "control of the narrative." The story of change needs to be coherent and clear. In the most successful *Learning Tomorrow* programs, school, community, and family partners constructed the narrative collaboratively. The shared control made for a stronger narrative than any of the parties could have developed individually.

At Augusta High School in the small, rural community of Augusta, Wisconsin, the *Learning Tomorrow* team created a method to link the technology-enhanced work of students to people and needs in the town. A school-to-work project for students, many of whom were facing financial difficulty, stressed business and communications skills, including multimedia applications. Business and community leaders served as mentors and often employed these students as interns. The students created brochures, video presentations, pamphlets, and slide presentations for community service organizations. Thus, they became proficient technology users, experienced workers, and responsible adults.

Assessment through Technology-Based Learning

While assessment is always important, extra emphasis on assessment for at-risk students is warranted in order to understand past performance patterns and to generate a better basis for advising and mentoring these students. Teachers realize that scores on high-stakes tests are a fixed aspect of today's school environment, but they continue to search for assessment tools keyed to instruction so they can track what and how students are learning and what kind of help students need to gain knowledge and master concepts.

Technology integration can provide several useful tools for assessment. Powerful databases and documentation tools are part of most technology systems. Making these archival records available for review and reflection by teachers, administrators, parents, researchers, and the students themselves is both possible and advisable.

Multimedia presentations by at-risk students can be an academic highlight

Video records of student work, electronic portfolios, and searchable databases all work in the service of assessment—and they have the advantage of being sharable, immediate, and stable. Instructors and administrators have learned that involving the students in the assessment process is a sure way to engage them in improving their performance and giving them new analytical and process skills. For many at-risk youngsters who have not been recognized or taken seriously in the past, preparing presentations of their assessment documents for parents, school boards and community members is the highlight of their school careers.

Diverse products and outcomes from student technology applications can build an assessment record

Evaluation work at *Learning Tomorrow* sites suggested that while teachers were often accumulating valuable assessment material, they did not always realize this, or were uncomfortable taking advantage of the material. Samples of student work over time constituted a record. Work on websites or presentation materials was a snapshot of a student's developing grasp of content and technique. Although portfolios were developed and used with students and parents, teachers seldom were able to translate the documentation into clear assessment information. This may be an area in which focused professional development could lead to strong skills and tools to embed assessment into everyday classroom work, informing students, teachers, and parents.

More work needed in assessment models

The thoughtful development of assessment instruments and techniques centered in technology is needed throughout the U.S. educational system, not only for at-risk students. A great many of the results of technology-infused education—project-based learning, ability to discriminate and synthesize, effective communications techniques in various media—are beyond the range of standard assessment tools. All students need better evaluation on these skills, and these skills need to be more fully valued and measured. It may be that work with at-risk students will be seen as the leading edge of more valid assessment techniques for all students.

Conclusion

Shared vision and commitment to change, based in and supported by technology, can make a school a very different place. The differences are both subtle and obvious. Programs that work have the respect of administrators and other teaching staff. This respect is won through the demonstration of teaching skill and dedication of staff and through the improved performance and achievement of the students. These programs represent high goals, not just getting by. They offer mastery, not remediation. They mobilize all resources to make the shared vision a reality.

Technology investment can result in improved student performance

Both educators and students are proud to be part of these programs. They are not hidden away, as alternative or optional programs for at-risk populations so often are. In fact, they are in the spotlight. Many students in *Learning Tomorrow* projects became skilled presenters at school and community meetings. Some of them had experienced painful failure in public speaking in the past. Their success in making effective presentations with the help of sophisticated software and graphics was especially rewarding.

Investing in technology is a proven strategy to improve student learning, but it is clear from NFIE's *Learning Tomorrow* program and other research that the investment must reach well beyond hardware and software. To transform schools and students, technology integration must reflect shared commitment to create a positive, productive school culture focused on teaching and learning in new ways. Learning goals for students, not technology goals, must come first. In addition, successful integration of technology for at-risk students depends on the teachers who are knowledgeable, have opportunities for continuous collegial learning, and who challenge their students academically while providing the support to ensure their success.

"At-Risk Students: Technology's Particular Promise" is one of several papers included in *Connecting the Bits, A reference for using technology in teaching and learning in K–12 schools*, issued by the National Foundation for the Improvement of Education in 2000, and available at www.nfie.org.

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Through an interview with Barbara Means, an authority on technology in education, this article provides a framework to view technology as a tool to transform teaching and learning and to advance the goals of education reform. Means discusses her research findings and highlights their relevance to current educational settings.

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This issue brief argues that a transformation not only of the basic assumptions about the teaching and learning process, but also the kinds of technology applications typically used in classrooms serving at-risk students must occur to enable at-risk students to succeed in a curriculum that stresses composition, comprehension, and application of skills.

Means, B. and M. S. Knapp. 1991. Rethinking teaching for disadvantaged students. Introduction to *Teaching advanced skills to at-risk students: Views from research and practice*, edited by B. Means, C. Chelemer, and M. S. Knapp. San Francisco: Jossey-Bass.

This book presents six instructional models for teaching at-risk students. A commentary section by an educational expert follows each chapter. Chapter one contrasts compensatory education as it is today with the kind of curriculum and instruction that would emerge based on the principles espoused in later chapters.

Means, B. and K. Olson. 1995. *Technology and education reform. Volume I: Findings and conclusions. Studies of education reform*. Menlo Park, Calif.: SRI International.

This document presents findings of a study that examined whether technology could provide significant support for constructivist, project-based teaching and learning approaches. It also identifies the elements necessary for effective implementation of technology within an educational reform context. Data were derived from case studies that were conducted at nine sites whose programs emphasized education reform and provided authentic activities for students from economically disadvantaged backgrounds.

Means, B., J. Blando, K. Olson, T. Middleton, C. C. Morocco, A. R. Remz, and J. Zorfass. 1993. *Using technology to support education reform*. Washington, D.C.: U.S. Department of Education, Office of Educational Research and Improvement.

This book discusses the use of technology for promoting reforms in American education. In addition to describing elements of school reform, the book discusses how technology can support student learning as well as teacher efforts to promote student learning. The book also includes a literature review on the effects of technology on student learning outcomes. The final chapter deals with issues of implementation for projects attempting education reform supported by technology.

Mendrinos, R. B. 1997. *Using educational technology with at-risk students: A guide for library media specialists and teachers*. Greenwood Professional Guides in School Librarianship. Westport, Conn.: Greenwood Press.

This guide offers library media specialists and teachers solutions and practical applications of educational technology within subject disciplines to help improve the achievement of at-risk students. Included are lesson plans, successful case studies, and project ideas for replication in language arts, science, and social studies. It also contains extensive lists of Internet addresses and other technology resources and a bibliography of further reading.

Moursund, D., T. Bielefeldt, S. Underwood, and D. Underwood. 1997. The Road Ahead: 1995-1997. Paper prepared for the National Foundation for the Improvement of Education. Eugene, Ore.: ISTE.

This report summarizes findings and recommendations from *The Road Ahead* program. The program included school-community partnerships; grants to design and implement activities using new technologies; and support systems such as mentors, conferences, and an on-line network. In addition to site profiles and recommendations, the report discusses findings regarding student learning, professional development, technology use, systemic change, factors that helped and hindered programs, and program support.

Ogle, D. M. 1997. Rethinking learning for students at risk. *Pathways Critical Issue*. Oak Brook, Ill.: North Central Regional Educational Laboratory. From web site www.ncrel.org/sdrs/areas/issues/students/atrisk/at700.htm.

This issue brief discusses how to ensure meaningful, engaged learning for all students by developing whole-school programs in which classroom teachers, specialists, administrators, and support staff collaborate to provide improved school-wide instruction. Strategies for promoting learning for at-risk students can be enhanced by appropriate assessment, ongoing professional development, and parental involvement.

Palincsar, A. and L. Klenck. 1991. Dialogues promoting reading comprehension. In *Teaching advanced skills to at-risk students: Views from research and practice*, edited by B. Means, C. Chelemer, and M. S. Knapp. San Francisco: Jossey-Bass.

One of six instructional models for teaching at-risk students in the book, this chapter describes two programs aimed at instilling the comprehension and composition skills of critical literacy, arguing for a fundamental change in the school as a whole.

Poirot, J. and G. Robinson. March 1994. Parent involvement and technology with at-risk students. *Computing Teacher* 21(6): 44-45.

This third in a series of articles on the use of technology with at-risk students focuses on using technology for increased parental interaction. Highlights include the effects of parental involvement on student achievement and self-esteem; and the use of telephones, videos, software, classroom computers, and integrated learning systems.

Princeton Survey Research Associates. 1993. *National education association communications survey: Report of the findings*. Princeton, N.J.: Princeton Survey Research Associates.

The report provides the results of a national telephone survey of 1,206 regular education teachers. Conducted on behalf of the National Education Association, the survey reports on the incidence of school-provided educational technology and assesses teacher perceptions of their effects on the education process.

Richman, J. A. 1994. At-risk students: Innovative technologies. *Media and Methods* 30(5): 26-27.

This article describes how innovations in educational technology contribute to motivation and achievement in the Berkshire Union Free School District (New York), a public school for at-risk students. Highlights include classroom presentation stations; examples of student multimedia projects; and state and federal recognition for the school. A list of resources on at-risk issues is included.

Rockman, S. 1995a. Facilitating change: NFIE's Learning Tomorrow project and school reform. Submitted to the National Foundation for the Improvement of Education. San Francisco, Calif.: Rockman et al.

This report documents the accomplishments of *Learning Tomorrow* program sites in the Southeast, and identifies how the process of facilitating and encouraging change with technology succeeds in generating school reform. It describes the *Learning Tomorrow* program, highlights achievements from particular sites, and provides in-depth case studies of four sites. The report discusses school and classroom changes that evolved, the improved attitudes and intellectual growth that students attained, and the professional and personal development of teachers involved in the project.

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This report documents the accomplishments of *Learning Tomorrow* sites in the Northeast. This program and *Learning Tomorrow* in the Southeast provided information for designing the national *Learning Tomorrow* program.

Samson, G. E. et al. 1986. Effects of computer-based instruction on secondary school achievement: A quantitative synthesis. *AFDS Journal* (summer): 312-326.

Soska, M. 1994. An introduction to educational technology. *Directions in Language and Education* 1(1).

This report discusses advances in computer-based technologies that can be used for teaching limited-English-proficient (LEP) minority students. These technologies offer multisensory delivery, increased self-expression and active student learning, cooperative learning, communication skill practice, multicultural education, and enhanced motivation. Two computer programs are recommended and detailed: Computer Education for Language Learning (CELL) and Alaska Writing Program (AWP).

School-Home-Community Learning Connections: Roles of Information Technologies

Introduction

The home, the school, and the community are the most important influences on a child's education (U.S. Department of Education 1986; Microsoft Corporation 1996). Parents are their children's first teachers, responsible for overseeing their cognitive, social, and emotional development and ensuring they start school ready to learn. Continued parental involvement throughout a child's years of schooling has a strong positive impact on learning.

The community also influences the education of children. The concept of community includes many groups such as neighbors, friends, relatives, and organizations such as religious institutions, local businesses, recreational and service organizations, and civic groups. Through technology the concept of community now also extends to the global community, made possible by instantaneous access to people and organizations throughout the world. The community contributes to children's education by shaping their values, offering a wide range of social experiences and occasions for interaction with different kinds of people and providing resources, knowledge, and opportunities for learning inside and outside of school. Once young people graduate from school, the community continues to be a place where they can apply their knowledge and learn throughout their lives.

This paper discusses

- how information technologies are transforming the educational roles of school, home, and community;
- how technology-enhanced partnerships can help children to learn more;
- what elements of technology partnerships characterize successful programs;
- an annotated bibliography

Information technologies are expanding and strengthening the relationships among school, home, and community, creating new possibilities for children to learn in diverse settings and different modes. Recognizing the value of these relationships, *The Road Ahead* program made school-home-community partnerships one of its primary goals. Each of the twenty-two sites was required to establish or promote a partnership with another entity in the community. The projects forged partnerships with a wide range of institutions, including police departments, museums, libraries, senior centers, child care programs, nature centers, colleges and universities, and businesses.

School, Home, and Community: How Information Technologies Are Transforming Their Educational Roles

As underscored by findings from cognitive science, the social context is very important in helping children to construct meaning and build knowledge. During the Industrial Age, learning became separated from the daily life of the community, compartmentalized within the confines of schools designed to accommodate an assembly line workplace (Abbot 1995). In response to changing societal needs, many schools and communities are working to create dynamic learning environments, in which individuals learn through collaborative interactions and take responsibility for their own learning. As they become increasingly common in schools, homes, and community settings, informational technologies can help to accomplish this goal.

Technology extends learning beyond school walls

The communication avenues opened through digital networks, video, email, the World Wide Web, and other technologies link students and teachers with learning opportunities not bound by location or physical structure. Technology-enhanced school-home-community partnerships are dissolving the walls that have traditionally defined "school" as a distinct place in the community where children go to learn during certain times of the day. Instead the learning environment is extended to include the home, other community sites, and the virtual world and is accessible any time of day. People who might not normally participate in school-based activities are drawn into the learning process by the lure of new modes of interaction. Students' interests are piqued by the appeal of going, at least virtually, outside their classroom walls.

The following examples from *The Road Ahead* sites illustrate some of the potential:

> In Phoenix, Arizona, students at an inner-city high school learned about Chinese culture through a technology partnership with a "sister cities" organization. Students from Chengdu, China, came to Arizona for a "winter camp" where they learned to use computers, while the local students learned about Chinese culture and developed presentations about the United States to share with their visitors. Later on, two of the American students went to China as part of a sister cities delegation, where they visited a Chinese school.
>
> In Anchorage, Alaska, a technology-enhanced partnership with a senior citizens' home spurred junior high students to interview seniors about local history and create a video "virtual museum" of Alaska's past. The students also taught computer skills to the residents and aides at the home.

Information technologies are also changing the roles of students, parents, educators, and community members within the learning process. Students, who often have more technology expertise than parents and community members, may become teachers as well as learners in a technology-enhanced partnership, educating adults about how to use new technologies. In the Anchorage project the students had to learn how to tailor their computer instruction to many adults who were unfamiliar with computers or keyboarding.

Technology changes roles in learning process

The role of the teacher also shifts, from a deliverer of instruction to a facilitator of learning who helps students access knowledge and resources from many sources. At the same time, the teachers learn more about how to craft effective partnerships. Parents and community members become lay educators who share their knowledge and experience while they, too, learn new skills.

Consider these examples from *The Road Ahead* sites:

> In Eau Claire, Wisconsin, *The Road Ahead* project connected elementary school students with a senior citizens center and a museum. Students posted an email "question of the week" about local history, which senior citizens answered. In addition to learning about local and state history, the children learned how to use digital scanners and digital cameras and to make multimedia presentations and hyperstacks. Among the students' products were a CD-ROM with a historical walking tour and a bilingual counting book in Hmong, the language of many immigrants in the community.
>
> In South Burlington, Vermont, a partnership between a school and a recreation department brought together high school students, parents, children in after-school programs, and other community members. The high school students helped the adults learn computer skills and advanced presentation skills.

Technology-Enhanced Partnerships: How New Connections Help Children Learn More

Educators around the country have recognized the potential of new school-home-community connections to improve student learning and have organized partnership programs with technology at their center.

These partnerships have a variety of purposes, but among the most common are those that aim to

- **increase parents' involvement in their children's education;**
- **connect students with learning resources in the wider community;**
- **create community hubs for learning and social services;**
- **forge collaborations with businesses, government, and community-based organizations to improve technology planning and education.**

Increasing Parental Involvement

As reported by NFIE (1996), "The top issue on teacher's minds when they think about education is parents. Teachers' highest priority for professional development is learning how to reach out to involve parents more effectively in their children's learning."

Information technologies can make it easier for parents and educators to communicate regularly. They can encourage parents to play a greater role in supporting their children's schoolwork and participate in family learning activities. Information technologies can also be a catalyst for reaching parents who have traditionally felt disconnected from schools. For example, communicating by email may be less intimidating for some than coming to the school building and talking to a teacher. Talking about computers can be an icebreaker that leads to deeper conversations about learning. Parents can also use these technologies to improve their own literacy and parenting skills.

Through telecommunications technologies, parents gain access to a world of information that can help them support their children's learning—anything from a science website to a parent chat room to a G.E.D. course. Parents and children can engage in family learning activities together on the computer or via the Internet. Working together on the computer can be a catalyst for parents and children to spend more quality time together.

Many homes, however, do not have access to information technologies, and many parents do not have basic computer skills. Some programs around the country have used the strategy of providing students with computers to use at home and at school and providing parents with training and at-home learning activities. Establishing online connections between home and school is a critical component of these projects. In many rural and inner-city areas, community technology centers are attempting to bridge the divide between those with and without home access. These centers often collaborate with schools in their communities.

Technology increasing parental involvement

The goal is to make email communications between home and school a regular part of the educational process. Parents and teachers can have structured conversations about students' work and academic progress. Teachers can send home reports and assignments via email, inform parents about upcoming events, request permission slips, or take care of other routine communications. Parents can ask questions about homework and curriculum, express concerns, provide information they might be less inclined to talk about face to face.

One such effort is Indiana's *Buddy System* project, which since 1987 has supplied every student and teacher in selected schools with computers, modems, printers, and software, both at home and school. This project has afforded access to computers and telecommunications to parents and families who would not otherwise have had them.

An example of parental involvement

Through the project, parents have received training in basic computer skills. As one activity, teachers assigned writing projects as homework and asked parents to comment on them. In addition, teachers have asked parents or family members to write something themselves. The telecommunications aspect of the project has been particularly useful; teachers have used it to communicate daily with families in a non-threatening way (Rockman 1995).

As reported in the Rockman study, the *Buddy System* program has had several positive impacts on the education of participating students. It has significantly improved students' writing achievement, increased their engagement in academic tasks, and improved teacher skills by providing effective professional development. Rockman also notes an increase in students' interest in and attention to mathematics, although it has not been reflected in higher test scores. In a 1994 study, Miller and McInerney reported a similar finding.

The Rockman study also found positive outcomes for families, including greater parental involvement and improved family climate. The *Buddy System* has enhanced the level of communication between family members and teachers and increased parents' monitoring of their children's schoolwork. Families have reported working, learning, and playing together. In addition, parents have used the computer for their own goals, such as preparing papers for classes, studying for a G.E.D., or filling out job applications.

Parental involvement resulted in positive outcomes

To improve the project, Rockman recommended increased integration of home and school activities, more professional development, expanded use of telecommunications to connect home and school, and use of *Buddy System* graduates as resources in the community.

Another program, the *Apple Classrooms of Tomorrow*, began providing home and school computers to selected sites in 1986. Studies of this effort found that it increased student engagement, improved achievement in some subjects, and encouraged teachers to use more student-centered instructional approaches (Apple Computer 1995).

Connecting Students with Community Learning Resources

Every community has a wealth of individuals with knowledge, skills, experience, enthusiasm, and other resources to contribute to children's learning. In a global online community, these resources are almost limitless. Technology can help schools identify and tap these resources.

Linking to outside experts

One project to link schools with outside experts in a range of disciplines is the *Electronic Emissary* project based at the University of Texas at Austin (Harris, O'Bryan, and Rotenberg 1996). Since 1993 the *Electronic Emissary* has connected classroom teachers and their students with professional experts who serve as advisors to classroom projects. For example, middle-school students conducting a biology project in a rural California school received guidance from a researcher at Michigan State University; a Texas elementary school class gained insights for a study of early colonial history from an historian in Virginia; and a New England high school genetics class discussed scientific theory and ethics with a geneticist in Minnesota.

The Knowledge Society model developed by Scardamalia and Bereiter (1996) sought to overcome the one-way flow of knowledge that characterized earlier "ask the expert" approaches. This model enables school children, university students, museum staff, businesses, and other network participants to share and modify common databases. For example, museum staff working on an electricity exhibit and elementary students studying electricity may use one another's databases as resources. "By visiting the students' databases, the curators will gain an understanding of students' conceptions (and misconceptions) of electricity, and the students will have input to the design of the exhibit."

Other projects are more local in their focus. Reissman (1995) described her experiences using computer, video, and audio technology to connect students to adults in the community. She assigned seventh-grade students of diverse ethnic backgrounds a conventional task of reading and critiquing current news articles.

Linking to adults in community

Reissman, however, added a novel requirement. The students interviewed an adult, recorded their correspondent's comments on the article, and prepared multimedia presentations on the topic. Reissman reported that the students explored issues over a period of time, encountered unexpected cultural perspectives, and spontaneously sought other points of view beyond the minimum requirement. "Interestingly," she wrote, "the ongoing partnerships were often valued by the adults . . . as well. Many unrelated retirees wrote to tell me and their student co-commentators how they really enjoyed talking about the news and hearing how 'young people felt.'"

Some projects have sought to pair successful adults in minority communities with minority students, with the goals of helping students improve their self-esteem and increase their appreciation of their own or other minority communities (Moll and Gonzalez 1994; Paratore et al. 1994; Swick 1995).

Whether global or local, these types of interactions can improve students' understanding of subject-matter content. Students get a better sense of what a practicing botanist does, for example, and how the study of biology in school relates to people's lives in the real world. Students can also gain maturity and confidence by corresponding with experts, adding information to multisite research studies, or designing products that will be seen and used by others. Students who connect with a global community can learn about other cultures at the same time they learn about the particular topic they are studying. In addition, their motivation is often greater with such learning experiences than with traditional methods of instruction.

Positive outcomes from community links

These kinds of projects can benefit schools and communities as well as students. Schools, for example, may develop a constituency of community people who will advocate for and become involved in other school ventures. In the *Buddy System* program ties formed through the project helped to facilitate other school reform efforts. Projects may create new bonds between people from different segments of the community who have all too few opportunities to interact in their daily lives, such as those from different generations or from diverse ethnic and cultural backgrounds.

Community groups may also strengthen their technology skills and infrastructure. In South Burlington, Vermont, for example, the whole community began using technology more as a result of *The Road Ahead* project. Students may gain new understanding of citizenship and become more involved in improving their community. In this respect, technology can help to rebuild a sense of community that has dwindled in today's mobile and segmented society.

Creating Community Hubs for Learning and Social Services

Technology-enhanced collaborations have strengthened the role of the school as an educational hub for the whole community. In several *Road Ahead* sites, adults, family members, and other community members have come to the school to learn new skills or participate in school activities, but this does not mean that the school is the only locus for learning. Partnerships have also strengthened educational opportunities for children and adults in other sites within the community, such as museums and recreation centers.

Creating new venues for learning

Establishing educational programs outside of school can have special advantages. For example, programs in community-based organizations may offer a less structured environment with more freedom for students to do hands-on projects. Collaborative projects with businesses can help students better understand the relationship between school and the world of work and can expose them to technological applications not available elsewhere.

Many schools have begun to play a major role in building and maintaining links that enable community agencies to meet the social services needs of disadvantaged students (Burnett 1994). Technology comes into play in these partnerships as service agencies take advantage of shared, networked databases to identify needs and assess results (Council of Chief State School Officers 1995). Capper (1994) reported on an inner-city service consortium based in a housing project and noted that community members felt that the services were more accessible than when they were housed in another (sometimes intimidating) public institution. On the other hand, Ascher (1990) maintained that the school is often the logical community center and can provide the most efficient delivery of services.

Forging Collaborations to Improve Technology Planning and Education

Business—public involvement in technology education increases broad support

The excitement of planning and implementing a technology-based partnership often provides a stimulating new reason for groups to come together that normally would have little interaction with the schools or with each other. Once they get together, however, they realize they have mutual interests. They realize they can accomplish more by developing reciprocal roles and sharing resources than any one group could alone. The joint planning, decision-making, and budgeting that occurs through these technology collaborations sometimes carries over to non-technology-based aspects of curriculum or community life.

Many school districts or schools have found it valuable to involve the community in their long-range technology planning processes. Some have established technology planning subcommittees or advisory councils, consisting of teachers, administrators, parents, business leaders, and other community members. Such groups can help the community "buy into" the technology plan and can be a source of ongoing advice once the plan is implemented.

They can also serve as a base of committed people for other school-community partnerships that involve technology. For example, in Canandaigua, New York, a large-scale committee, including representatives from private industry, planned a comprehensive technology effort for the school district. The end result was a system of networks, labs, multimedia workstations, and a TV studio. Any student with a Windows-based computer, a modem, and the proper software could link to the district's extensive CD-ROM collection. Parents and other family members could also use this resource (Braun and Bielefeldt 1995).

Within *The Road Ahead* program—itself a business-education partnership between Bill Gates of Microsoft Corporation and the National Foundation for the Improvement of Education—a number of sites pursued school-business collaborations.

A Vermont high school's digital imaging lab cooperated with the local computer animation industry. A South Carolina elementary school augmented its computer facilities with donations from a software firm, which sees itself as investing in the technical education of its future employees. In Greece, New York, a civil engineering consulting firm formed a partnership with a middle school to design and construct a fitness trail for community use.

Several sites in *The Road Ahead* discovered that assumptions about schedules and learning needs were different for schools and their partner organizations (which also include, at different sites, senior care facilities, libraries, museums, nature centers, police departments, and youth programs). Some partnerships found that they had to make changes in meeting times, work schedules, and the content of activities to meet participants' needs (ISTE 1996).

Elements of Successful Partnerships

Studies of successful community partnerships in general (Grobe 1993; Imel 1991) and technology partnerships in particular (ISTE 1998; Thompson 1995; Apple Computer 1995) have identified certain conditions that tend to be present in most successful programs.

They include the following elements:

- **top-level leadership**

  Partnerships are usually instigated by a school or community leader (or both) with a vision. Who these leaders are depends on the partners and their relationships, but often they are "spark plug" individuals with the authority and persuasiveness to energize others and convince them to stay the course. (For a school or district-wide effort, it also makes a real difference to have support from the principal or the blessing of the superintendent, even if they are not directly involved with the specific project.)

  Leadership means promoting the project, getting others interested and involved, providing necessary resources, and holding staff accountable for results. In *The Road Ahead* projects, vision came from key individuals, such as technology coordinators, teachers, directors of community-based agencies or organizations, and business people.

- **grounding in community needs**

  A needs assessment is an effective tool for building consensus and creating shared ownership. Data about such issues as a lack of technology access or inadequate student performance can motivate people to take steps to fill the gaps.

  This process should also look at needs within the larger community that could be addressed through a technology-based partnership—anything from providing employers with students who are well prepared for local jobs to ending social isolation of residents in a nursing home. It is also crucial for the partners to understand local social and economic needs and the local political climate.

- **attention to infrastructure**

  To take root and thrive, technology-based partnerships require not only the hardware and software but also other kinds of infrastructure, such as adequate staff, professional development, and technical support.

  Educators must recognize that community-based organizations generally have a more fragile infrastructure than schools, characterized by higher turnover among organizational staff, lower availability of professional development, and a lack of hardware and software. This point was brought home to several projects in *The Road Ahead* program when they encountered continually changing personnel or other frustrating delays.

- **effective public relations and community outreach**

  Partnerships need to build and maintain support for their efforts. Partners need to be kept apprised of activities and accomplishments. Often, it is desirable that a partnership be thoroughly reported by the press and media. The project must have strategies for outreach that will involve all elements of the community, including diverse ethnic, racial, and economic groups. Inclusion of all such constituencies is a critical component.

- **strategic planning and delineation of responsibilities**

  It is important to agree on a mission statement and put it in writing; to set goals and measurable outcomes; to develop a formal implementation plan that details activities, responsible persons, and timelines; and to develop a process for monitoring and evaluating progress. Articulating and agreeing upon roles and responsibilities (who will do what and when and where) is an essential step of this process, one that should be done early on.

- **shared decision making and interagency ownership**

  To achieve a true partnership, schools must work with parents and community organizations on an equal footing, rather than one group calling the shots. Partners must be prepared to share decision making and responsibility.

Relationships based on trust, open communication, and shared credit and recognition are critical. Part of this process requires understanding that organizational partners may have different cultures, different bureaucratic structures, and diverse ways of doing things. A sense of ownership among all local partners is especially critical to the survival of collaborations developed as a result of outside grants. All the partners must feel they are benefiting from the arrangement.

- **appropriate resources and technical assistance**

Obtaining the needed resources—not just funding but human and in-kind support—is one of the most vexing problems confronting partnerships. While businesses may donate equipment and parent-teacher groups may raise money, there are likely to be other funding needs that will be met only by persistently recruiting other donors.

Human resources may be the most critical element in some programs. Apple Computer (1995) found that partnerships created to affect teaching and learning require extra time for teachers and intensive professional development. Funding for ongoing technical assistance is an especially important need, and a budget for this purpose should be built into the plan developed by the partners.

- **patience, vigilance, and flexibility**

Change takes time. Several of *The Road Ahead* projects had slow starts due to such obstacles as hardware and software installation problems, difficulty in recruiting community participants, or bureaucratic barriers. These partnerships sucessfully overcame initial obstacles because each of the partners had a sense of ownership as well as a long-term commitment to the attainment of their shared goals.

Above all, these partnerships were flexible enough to adapt their strategies to changing circumstances—a point emphasized over and over again among project sites. Leaders were also willing to assign time, money, and human resources to maintain the partnership. Ongoing community outreach is essential, along with expanding involvement and activities. Partnerships that are not growing are very likely dying.

Conclusion

Building partnerships among schools, families, and other community groups can strengthen technology-enhanced learning. When these connections are well established, families are more involved and supportive of the educational process, communities are more committed to their schools, and schools have a better understanding of both the needs and the resources in the community.

Technology in education can create new models of communication

Educators and researchers are increasingly working to turn this vision of partnership into a reality, but change takes a great deal of time, planning, training, commitment, and patience. Information technologies can facilitate this kind of change by offering new modes of communication among schools, homes, and communities. They can provide a fresh and exciting motive for parents and citizens to become involved in children's learning or to learn new skills themselves.

For technology-enhanced partnerships to work, however, all participants must be motivated by mutual concerns and treated with respect. Goals, roles, and objectives must be clearly delineated. Finally, excellent communication skills, with a focus on listening, are a prime requisite to success at every step of the way.

"School-Home-Community learning Connections: Roles of Information Technologies" is one of several papers included in *Connecting the Bits, A reference for using technology in teaching and learning in K–12 schools,* issued by the National Foundation for the Improvement of Education in 2000, and available at www.nfie.org.

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