Critical Issue: Using Technology to Improve Student Achievement

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**ISSUE:** Because effective use of technology must be supported by significant investments in hardware, software, infrastructure, professional development, and support services, over the last decade, we as a nation have invested more than $66 billion investment in school technology (QED, 2004). This unprecedented level of investment in educational technology has raised expectations of legislators and the public who are now looking for returns on this investment (Benton, 2002; CEO Forum, 1999, 2000), and therefore are calling for evidence regarding the efficacy and cost-effectiveness of technology in K-12 schools (Ringstaff & Kelley, 2002; Panel on Educational Technology, 1997; Melmed, 1995).

While complex factors have influenced the decisions for where, what, and how technology is introduced into our nation's school systems, ultimately, the schools will be held accountable for these investments. How can schools ensure that the promise that technology holds for student achievement is realized? What factors need to be in place to support the effective use of technology? What resources can school districts use to help them plan for technology that will have a positive impact on student achievement, and how can they justify that investment?

To answer these questions, educators need to look at the research on technology and student achievement and the contextual factors that affect learning goals. In this updated briefing (originally published in 1999), we examine current research perspectives and findings on using technology to improve student achievement.

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CONTEXT

Technology and Youth: Wired Schools and Wired Lives

A decade ago, access to technology was limited and wiring schools was one of the nation's highest education priorities. Ten years of substantial investments have vastly improved this picture. According to the *Secretary's Fourth Annual Report on Teacher Quality*, virtually every school with access to computers has Internet access (99%), compared to only 35 percent of schools in 1994, according to the National Center for Education Statistics (NCES) (Parsad & Jones, 2005). Public schools have also made consistent progress in expanding Internet access in instructional rooms, according to NCES. In 1994, 3 percent of public school instructional rooms had Internet access, compared with 93 percent in 2003. And between 1998 and 2003, the student-to-connected-computer ratio went from 12-to-1 to 4.4-to-1.

Along with expanded access has come a growing pervasiveness of technology in society. For a generation of young people, technology, particularly the Internet, has assumed a substantial stake in their social and educational lives. A recent survey conducted by the Pew Internet & American Life Project (Hitlin & Rainie, 2005) found that roughly 21 million youth between the ages of 12 through 17—approximately 87 percent of the entire age bracket—use the Internet. Of those 21 million online teens, 78 percent (about 16 million students) say they use the Internet at school. This translates into 68 percent of all teenagers, up from 47 percent in 2000. The survey also found that most teens believe that the Internet helps them do better in school (86 percent of teens, 88 percent of online teens).

In a previous survey, the project found that 71 percent of online teens said they relied mostly on Internet sources for the last big project they did for school and 34 percent of online young people ages 12-17 download study aides from the Internet. (Lenhart, Rainie, & Lewis, 2001). The U.S. Bureau of the Census (2003) found that 57 percent of all children in school ages 7-17 use a home computer to complete school assignments. Young people are also taking advantage of new, powerful communications tools. Three-quarters of online teens use instant messaging , representing close to 16 million youth. Of those 16 million, 78 percent say they use instant messaging from time to time to talk about homework, tests, or schoolwork.

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NCLB & High Stakes Testing

With the passage of the No Child Left Behind (NCLB) legislation in January 2002, testing has become not only more routine, but also increasingly high-stakes and focused more on specific content knowledge. Test results are regularly used as the measuring stick for student advancement to the next grade and as a gauge for judging the quality of schools and the educators who work in them. Therefore, efforts to integrate technology into schools and classroom practices must not only acknowledge but also provide evidence that technology assists in meeting these accountability demands.

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Student Skills and ICT Literacy: Meeting the 21st Century Challenge

Greater emphasis on high stakes testing has prompted greater scrutiny on what's being tested and how it relates to what students need to know to succeed in society, in part fueled by the poor performance of U.S. students on the international assessments, PISA (Stage, 2005) and TIMSS (Mullis, Martin, Gonzalez, & Chrostowski, 2004), and rising concern about the relative competitiveness of the U.S. labor force. Government leaders ranging from Education Secretary Margaret Spellings (Spellings, 2005b) to former Secretary of State Colin Powell (Kagan & Stewart, 2004a) have signaled that today's students are not prepared to compete internationally. Education and business leaders have also begun to question whether current assessments focus too much on measuring students' ability to recall discrete facts at the cost of not adequately measuring students' ability to think critically and solve problems (Partnership for 21st Century Skills, 2005), which some researchers assert produce, at best, only illusory student gains (Ridgeway, McCusker, Pead, 2004).

This questioning reflects the technological and business changes brought about by the Web, wireless communication and distributed work, which Casonato & Morello (2002) note have "introduced discontinuity in where and how people work, how their performance is measured, and how their objectives are set" where "assignments, work settings, peers, employers and work choices are increasingly changeable and fluid." The employer-centered workplace of predefined jobs and career paths has given way to a worker-designed environment where individuals pursue their own assignments and must effortlessly combine technical skills with an intellectual toolbox enriched with experiences, roles, team building, and knowledge (Casonato & Morello, 2002; Morello, 2003). Similarly, some argue that today's students, surrounded by digital technology since infancy, are fundamentally different from previous generations (McHale, 2005) and are no longer the people our educational system was designed to teach (Prensky, 2001).

As a result, a widening gap has formed between the knowledge and skills students are acquiring in schools and the knowledge and skills needed to succeed in the increasingly global, technology infused 21st century workplace (Partnership for 21st Century Skills, 2005b).

As a first step toward bridging this gap, NCLB requires states to demonstrate that "every student is technologically literate by the time the student finishes the eighth grade, regardless of the student's race, ethnicity, gender, family income, geographic location, or disability" (U.S. Department of Education, 2001). While NCLB has established an eighth-grade technology literacy requirement, the requirement is not a full statement of knowledge and skills students need nor does it include a mechanism for ensuring accountability (Kay & Honey, in press).

Numerous business, policy, and nonprofit organizations have developed policy reports and frameworks describing the need to improve children's higher-level technology-related skills and attempting to define those skills (Bertelsmann Foundation & AOL Time Warner Foundation, 2002; CEO Forum, 2001; NCREL, 2002; ISTE, 1999; ETS: International ICT Literacy Panel, 2001; Partnership for 21st Century Skills, 2003, 2005).

While many different terms have been used to describe what students need, such as digital literacy, technological literacy, and 21st century skills, education leaders, nationally and internationally, are beginning to come together around a new common definition of what students need to know, Information and Communication Technology (ICT) Literacy. ICT Literacy reflects the need for students to develop learning skills that enable them to think critically, analyze information, communicate, collaborate, and problem-solve, and the essential role that technology plays in realizing these learning skills in today's knowledge-based society. Representative of the ICT literacy skills are the following six arenas critical to students' success in the workplace (Kay and Honey, 2005):

- Communicate Effectively: Students must have a range of skills to express themselves not only through paper and pencil, but also audio, video, animation, design software as well as a host of new environments (e-mail, Web sites, message boards, blogs, streaming media, etc.).

- Analyze and Interpret Data: Students must have the ability to crunch, compare, and choose among the glut of data now available Web-based and other electronic formats.

- Understand Computational Modeling: Students must posses an understanding of the power, limitations, and underlying assumptions of various data representation systems, such as computational models and simulations, which are increasingly driving a wide-range of disciplines.

- Manage and Prioritize Tasks: Students must be able to mange the multi-tasking, selection, and prioritizing across technology applications that allow them to move fluidly among teams, assignments and communities of practice.

- Engage in Problem Solving: Students must have an understanding of how to apply what they know and can do to new situations.

- Ensure Security and Safety: Students must know and use strategies to acknowledge, identify, and negotiate 21st century risks.

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Different Types of Technology and their Educational Applications

Many different types of technology can be used to support and enhance learning. Everything from video content and digital moviemaking to laptop computing and handheld technologies (Marshall, 2002) have been used in classrooms, and new uses of technology such as podcasting are constantly emerging.

Various technologies deliver different kinds of content and serve different purposes in the classroom. For example, word processing and e-mail promote communication skills; database and spreadsheet programs promote organizational skills; and modeling software promotes the understanding of science and math concepts. It is important to consider how these electronic technologies differ and what characteristics make them important as vehicles for education (Becker, 1994).

Technologies available in classrooms today range from simple tool-based applications (such as word processors) to online repositories of scientific data and primary historical documents, to handheld computers, closed-circuit television channels, and two-way distance learning classrooms. Even the cell phones that many students now carry with them can be used to learn (Prensky, 2005).

Each technology is likely to play a different role in students' learning. Rather than trying to describe the impact of all technologies as if they were the same, researchers need to think about what kind of technologies are being used in the classroom and for what purposes. Two general distinctions can be made. Students can learn "from" computers—where technology used essentially as tutors and serves to increase students basic skills and knowledge; and can learn "with" computers—where technology is used a tool that can be applied to a variety of goals in the learning process and can serve as a resource to help develop higher order thinking, creativity and research skills (Reeves, 1998; Ringstaff & Kelley, 2002).

The primary form of student learning "from" computers is what Murphy, Penuel, Means, Korbak and Whaley (2001) describe as discrete educational software (DES) programs, such as integrated learning systems (ILS), computer-assisted instruction (CAI), and computer-based instruction (CBI). These software applications are also among the most widely available applications of educational technology in schools today, along with word-processing software, and have existed in classrooms for more than 20 years (Becker, Ravitz, & Wong, 1999).

According to Murphy et al, teachers use DES not only to supplement instruction, as in the past, but also to introduce topics, provide means for self-study, and offer opportunities to learn concepts otherwise inaccessible to students. The software also manifests two key assumptions about how computers can assist learning. First, the user's ability to interact with the software is narrowly defined in ways designed specifically to promote learning with the tools. Second, computers are viewed as a medium for learning, rather than as tools that could support further learning (Murphy et al, 2001).

While DES remains the most commonly used approach to computer use in student learning, in more recent years, use of computers in schools has grown more diversified as educators recognize the potential of learning "with" technology as a means for enhancing students' reasoning and problem-solving abilities. In part, this shift has been driven by the plethora of new information and communication devices now increasingly available to students in school and at home, each of which offers new affordances to teachers and students alike for improving student achievement and for meeting the demand for 21st century skills describe earlier. No longer limited to school labs, school hours and specific devices, technology access is increasingly centered on the learner experience.

Bruce and Levin (1997), for example, look at ways in which the tools, techniques, and applications of technology can support integrated, inquiry-based learning to "engage children in exploring, thinking, reading, writing, researching, inventing, problem-solving, and experiencing the world." They developed the idea of technology as media with four different focuses: *media for inquiry* (such as data modeling, spreadsheets, access to online databases, access to online observatories and microscopes, and hypertext), *media for communication* (such as word processing, e-mail, synchronous conferencing, graphics software, simulations, and tutorials), *media for construction* (such as robotics, computer-aided design, and control systems), and *media for expression* (such as interactive video, animation software, and music composition).

In a review of existing evidence of technology's impact on learning, Marshall (2002) found strong evidence that educational technology "complements what a great teacher does naturally," extending their reach and broadening their students' experience beyond the classroom. "With ever-expanding content and technology choices, from video to multimedia to the Internet," Marshall suggests "there's an unprecedented need to understand the recipe for success, which involves the learner, the teacher, the content, and the environment in which technology is used."

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RESEARCH RESULTS

In their meta-analysis review of research conducted between 1993 and 2000 on the effectiveness of DES, Murphy et al (2001) found evidence of a positive association between use of DES products and student achievement in reading and mathematics, an association consistent with earlier reviews of the research literature on the effectiveness of computer-based instruction (e.g., Kulik & Kulik, 1991; Kulik, 1994; Fletcher-Flinn & Gravatt, 1995; Ryan, 1991). Students in the early grades, from pre-K to grade 3, and in the middle school grades appear to benefit most from DES applications for reading instruction, as do students with special reading needs.

In a 2000 study commissioned by the Software and Information Industry Association, Sivin-Kachala and Bialo (2000) reviewed 311 research studies on the effectiveness of technology on student achievement. Their findings revealed positive and consistent patterns when students were engaged in technology-rich environments, including significant gains and achievement in all subject areas, increased achievement in preschool through high school for both regular and special needs students, and improved attitudes toward learning and increased self-esteem.

O'Dwyer, Russell, Bebell, and Tucker-Seeley (2005) found that, while controlling for both prior achievement and socioeconomic status, fourth-grade students who reported greater frequency of technology use at school to edit papers were likely to have higher total English/language arts test scores and higher writing scores on fourth grade test scores on the Massachusetts Comprehensive Assessment System (MCAS) English/Language Arts test.

Michigan's Freedom to Learn (FTL) initiative, an effort to provide middle school students and teachers with access to wireless laptop computers, has been credited with improving grades, motivation and discipline in classrooms across the state, with one exemplary school seeing reading proficiency scores on the Michigan Education Assessment Program (MEAP) test, administered in January 2005, reportedly increasing from 29 percent to 41 percent for seventh graders and from 31 to 63 percent for eighth graders (eSchool News, 2005).

In examining large-scale state and national studies, as well as some innovative smaller studies on newer educational technologies, Schacter (1999) found that students with access to any of a number of technologies (such as computer assisted instruction, integrated learning systems, simulations and software that teaches higher order thinking, collaborative networked technologies, or design and programming technologies) show positive gains in achievement on researcher constructed tests, standardized tests, and national tests.

Cavanaugh's synthesis (2001) of 19 experimental and quasi-experimental studies of the effectiveness of interactive distance education using videoconferencing and telecommunications for K-12 academic achievement found a small positive effect in favor of distance education and more positive effect sizes for interactive distance education programs that combine an individualized approach with traditional classroom instruction.

Boster, Meyer, Roberto, & Inge (2002) examined the integration of standards-based video clips into lessons developed by classroom teachers and found increases student achievement. The study of more than 1,400 elementary and middle school students in three Virginia school districts showed an average increase in learning for students exposed to the video clip application compared to students who received traditional instruction alone.

Wenglinsky (1998) noted that for fourth- and eighth-graders technology has "positive benefits" on achievement as measured in NAEP's mathematics test. Interestingly, Wenglinsky found that using computers to teach low order thinking skills, such as drill and practice, had a negative impact on academic achievement, while using computers to solve simulations saw their students' math scores increase significantly. Hiebert (1999) raised a similar point. When students over-practice procedures before they understand them, they have more difficulty making sense of them later; however, they can learn new concepts *and* skills *while* they are solving problems. In a study that examined relationship between computer use and students' science achievement based on data from a standardized assessment, Papanastasiou, Zemblyas, & Vrasidas (2003) found it is not the computer use itself that has a positive or negative effect on achievement of students, but the way in which computers are used.

Researchers are also making progress on the more complicated task of investigating the impact of technology use on higher order thinking skills as measured through means other than standardized tests. They are examining students' ability to understand complex phenomena, analyze and synthesize multiple sources of information, and build representations of their own knowledge. At the same time, some researchers are calling for newer standardized assessments that emphasize the ability to access, interpret, and synthesize information.

Research indicates that computer technology can help support learning and is especially useful in developing the higher-order skills of critical thinking, analysis, and scientific inquiry "by engaging students in authentic, complex tasks within collaborative learning contexts" (Roschelle, Pea, Hoadley, Gordin & Means, 2000; Means, et. al., 1993).

While research linking technology integration, inquiry-based teaching, and emphasis on problem solving with student achievement is emergent, some research exists that suggests a connection. In a 2001 study of Enhancing Missouri's Instructional Networked Teaching Strategies (eMints) program, a statewide technology integration initiative, eMINTS students scored consistently higher on the Missouri Assessment Program (MAP) than non-eMINTS students, including eMINTS students classified as having special needs. The higher MAP results were found to be associated with the instructional practices (Evaluation Team Policy Brief, 2002). The eMINTS program provides teachers with professional development to help integrate technology so that they can use inquiry-based teaching and emphasize critical-thinking and problem-solving skills.

The program has since expanded to not only Missouri schools and districts but also other states as well. Currently, 232 Missouri districts, 10 Utah districts, 56 Maine districts, 2 Nevada districts, and 1 Illinois district, representing 1,000 classrooms and 22,500 students now take advantage of the eMINTS program offerings. Test results continue to show that, on most state tests, students enrolled in eMINTS classrooms scored higher than students enrolled in non-eMINTS classrooms and that low-income and special education students in eMINTS classes generally score higher than their non-eMINTS peers (eMINTS, 2005).

Results from other studies (Perez-Prado and Thirunarayanan 2002; Cooper 2001; Smith, Ferguson and Caris 2001) also suggest that students can benefit from technology-enhanced collaborative learning methods and the interactive learning process.

Roschelle, Pea, Hoadley, Gordin, & Means (2000) identify four fundamental characteristics of how technology can enhance both what and how children learn in the classroom: (1) active engagement, (2) participation in groups, (3) frequent interaction and feedback, and (4) connections to real-world contexts. They also indicate that use of technology is more effective as a learning tool when embedded in a broader education reform movement that includes improvements in teacher training, curriculum, student assessment, and a school's capacity for change.

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FACTORS TO CONSIDER

Inclusion: Reaching All Students

A major concern of many educators with regard to educational technology is its potential to exclude those who may not have access to it, or may not be able to use it. Regardless of what research may indicate concerning positive effects of technology on student learning, technology will be of limited use in achieving the goals of NCLB if is not available to all students.

Students at Risk. Research demonstrates that the challenge of helping teachers and students achieve ICT literacy, and the challenge of establishing frameworks for assessing their skills, is most acute in schools serving low-socioeconomic, minority students (Becker, 2000b; Becker & Ravitz, 1997).While public debate about the digital divide centers on basic technology access, the gap is even wider when measured by the pedagogical practices associated with technology use in different schools. More than half (53%) of teachers in public schools who have computers use them or the Internet for instruction during class. But in schools whose students are from higher-income families, 61 percent of teachers with computers use them in class compared to 50 percent of those teaching in schools with lower-income students (Lenhart, Rainie & Lewis, 2001). And as wired as many young people are, the same study that found 87 percent of young people use the Internet also found that 3 million remain without Internet access. Many of those without access come from financially disadvantaged backgrounds, and a disproportionate number are black (eSchool News, 2005a).

Schools serving students living in poverty tend to use technology for more traditional memory-based and remedial activities, while schools serving wealthier communities are more likely to focus on communication and expression.A nationwide study examining the relationship between socioeconomic status and teaching practices around technology found that teaching in low-SES schools correlated most strongly with using technology for "reinforcement of skills" and "remediation of skills," while teaching in higher-SES schools correlated most with "analyzing information" and "presenting information to an audience" (Becker, 2000b).

At the same time, although less studied than other outcomes, demonstration efforts and anecdotal evidence suggest that teaching ICT literacy skills (specifically those related to multimedia literacy in Web, publishing and video production) can improve the economic prospects of at-risk youth by giving them marketable skills (Lau & Lazarus, 2002).

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Language Learners. Likewise, in teaching language learners, using technology has distinct advantages that relate not only to language education but preparing students for today's information society. Computer technologies and the Internet are powerful tools for assisting language teaching because Web technology is a part of today's social fabric, meaning language learners can now learn thorough writing e-mail and conducting online research (Wang, 2005).

In Oregon secondary schools, wirelessly networked note taking is used to support Hispanic migrant students who speak English as a second language (ESL). As part of the InTime project, ESL students attend regular high school classes along with a bilingual, note-taking/mentoring partner. Note takers and students communicate using a collaborative word processing and graphics package on wirelessly networked laptop computers. During class presentations, ESL students can read their note taker's translation of key words, allowing students to build both English and Spanish literacy skills as they advance academically (Knox and Anderson-Inman, 2001).

Students with Disabilities. "For several decades, the American educational system has taken a narrow view of special education, treating it as a mini-school within the school where teachers, largely cut off from the rest of the staff, faced a group of students with an incredibly wide range of abilities and disabilities and made the best of it. Today, that view of special education is giving way to a broader, more philosophical approach—an approach designed to weave inclusive practices into the fabric of the whole-school environment." (MOSAIC, 2000a).

The shift in recognizing the needs of students with disabilities in relationship to their general education peers began with the 1997 amendments to the Individuals with Disabilities Education Act. Before the law, many children with disabilities who were not in schools at all because schools had chosen to exclude them (MOSAIC, 2000b). IDEA clearly established that all students with disabilities have the right to public education. More than 6 million children with disabilities ages 3 to 21 years old are served in federally supported programs (Snyder & Tan, 2005). However, students with disabilities frequently experience insufficient access to and success in the general education curriculum. This is especially true for adolescent learners, even non-disabled students, who must cope with the emphasis on learning from text (Biancarosa & Snow, 2004; Kamil, 2003).

Universal Design for Learning (UDL) takes advantage of the opportunity brought by rapidly evolving communication technologies to create flexible teaching methods and curriculum materials that can reach diverse learners and improve student access to the general education curriculum (Rose & Meyer, 2002). UDL assumes that students bring different needs and skills to the task of learning, and the learning environment should be designed to both accommodate, and make use of, these differences (Bowe 2000; Rose & Meyer, 2002). To promote improved access to the general curriculum for all learners, including learners with disabilities, Rose & Meyer (2002) have identified three key principles or guidelines for UDL:

1. Presenting information in multiple formats and multiple media.
2. Offering students with multiple ways to express and demonstrate what they have learned.
3. Providing multiple entry points to engage student interest and motivate learning.

For example, printed reading materials pose substantial challenges to the learning of students with disabilities (J. Zorfass: personal communication, October 2005). Technology can assist with such difficulties by enabling a shift from printed text to electronic text, which Anderson-Inman and Reinking (1998) assert can be modified, enhanced, programmed, linked, searched, collapsed, and collaborative. Text styles and font sizes can be modified as needed by readers with visual disabilities; read aloud by a computer-based text-to-speech translators; and integrated with illustrations, videos, and audio. Electronic text affords alternative formats for reading materials that can be customized to match learner needs, can be structured in ways that scaffold the learning process and expand both physical and cognitive access, and can foster new modes of expression through revision and multimedia (J. Zorfass: personal communication, October 2005). It represents one way that technology can support the achievement of students with disabilities.

Technology also has a role to play in the testing of students with disabilities. A notable outgrowth of NCLB is the legislation's mandatory requirement that states account for individual subgroups, which has further challenged schools and districts to acknowledge students with disabilities (McLaughlin, S Embler, K Nagle, 2004; Nagle, 2005). State academic content and achievement standards now define the goals of education for all students, and most students with disabilities are now expected to reach the same level of proficiency as their non-disabled peers.

In order to ensure that disabilities do not prevent students from participating in standardized assessments, students with disabilities are entitled to take these tests in the same way as their peers, with accommodations, or with an alternate assessment (Thompson, Thurlow, & Moore, 2003). These accommodations or alternatives must not alter the content standard being measured nor the achievement standard (McLaughlin, Embler & Nagle, 2004). While technology can support such accommodations and alternatives, striking a balance between accommodation and standardization across all students' testing experiences remains a subject of debate today (Murray, 2005).

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Educational Technology and Data Driven Decision Making

The effectiveness of educational technology on student learning depends not only on what outcomes are targeted and how the technology is integrated into instruction, but also on how teachers assess student performance in classrooms and adjust instruction accordingly. Technology offers teachers a broad range of tools to collect and analyze data, and richer sets of student data to guide instructional decisions.

NCLB has prompted educators to think much more systematically about educational decision-making and the use of data to inform their decisions about everything from resource allocation to instructional practice. Schools are now expected to monitor their efforts to enable all students to achieve, and administrators and teachers are now expected to be prepared to use data to understand where students are academically and to establish "targeted, responsive, and flexible" ways to improve this academic standing (Mitchell, Lee, & Herman, 2000, p. 22). However, despite encouragement at the policy level, there is growing consensus that schools are not adequately prepared for the task of routinely thinking critically about the relationships between instructional practices and student outcomes (Confrey & Makar, 2005; Olsen, 2003; Hammerman & Rubin, 2002; Herman & Gribbons, 2001; Kearns & Harvey, 2000).

Recent research conducted by EDC's Center for Children and Technology has found that educators working at different levels of a school system have distinctive intuitive approaches to the process, despite the absence of systematic training in a particular approach to data-driven decision-making. For example, school administrators use high-stakes test data to allocate resources and plan professional development and other kinds of targeted intervention activities by identifying general patterns of performance, class-, grade-, and school-wide strengths and weaknesses. Teachers tend to use multiple sources of data—homework assignments, in-class tests, classroom performances, and experiential information —to inform their thinking about their students strengths and weaknesses (Brunner, Fasca, Heinze, Honey, Light, Mandinach & Wexler, 2005; Light, Wexler & Heinze, 2004; Honey, Brunner, Light, Kim, McDermott, Heinze, Bereiter & Mandinach, 2002).

While drawing on varied sources of data to form opinions about students' competencies is not new behavior for teachers, significant research (Mandinach, Honey, Light, Heinze, & Rivas, 2005; Confrey & Makar, 2002, 2005; Hammerman, & Rubin, 2002, 2003) suggests that teachers examine factors that contribute to individual patterns of behavior and think case-by-case, rather than identify patterns in data at different levels of aggregation, from student-to-student, class-to-class, and year-to-year, and systematically analyze the relationship between student performance and instructional strategies and materials.

Data literacy—the ability of instructional leaders and teachers to work individually and collectively to examine outcomes-based achievement data, formative assessment measures of student performance, and students' work products, and to develop strategies for improvement based on these data—is now widely recognized as a critical strategy in the academic performance of schools (Fullan, 1999; Haycock, 2001; Johnson, 1996; Love, 2004; Schmoker, 1999; Zalles, 2005). A key concept of data literacy is generating only the data that are needed and making full use of what's collected. The National Research Council (1996) notes that, "far too often, more educational data are collected and analyzed than are used to make decisions or take action" (p. 90). Those resources become meaningful to educators only when they are transformed into information, and ultimately into usable or actionable knowledge (Mandinach & Honey, 2005).

Taken as a whole, the emerging research in this area suggests that what is needed is a comprehensive and purposeful approach to the use of data that not only informs the practices of individual teachers, but is supported as an essential and strategic part of school-wide improvement strategies. New professional development programs are now training teachers and school leaders in how to make use of data in systematic and rigorous ways to continuously improve student performance. For example, TERC has created Using Data, a professional development model that introduces teachers to a process through which they learn to frame questions, collect data, formulate hypotheses, draw conclusions, take action, and monitor results (Love, 2002).

Preliminary studies have indicated that this model has had an impact on teacher classroom behavior and on their approach to data analysis and interpretation (Love, 2004), and has also improved student learning as indicated by state and formative assessments (Zuman, 2005). Results from external evaluations of the intervention conducted in various locations have shown substantial gains in student performance on state accountability measures in the areas of math and language arts.

Technology has a vital role to play in enabling data-driven decision-making. Web-based test data reporting systems provide an interface to the state and city testing results by organizing raw data into information that is aligned with state standards and mobile computing devices, such as handhelds, provide teachers with a platform to administer and analyze the data of classroom-based assessments.

For example, according to the 2004 Quality Education Data, 55 percent of the nation's public school districts used PDAs or handheld PCs in the 2002-2003 school year with an additional 8 percent expected to purchase them for use during the 2003-2004 school year. The numbers released by Wireless Generation, a for-profit company that designs educational assessment applications for handheld devices, suggests an even greater increase.During the fall of 2005, Wireless estimates that roughly 80,000 teachers, working in 48 states will be using their software to collect and analyze data for up to one million students in pre-K through sixth grade. The company currently has contracts with ten Reading First states, as well as with some of the largest school districts in the nation, including the New York City Board of Education and Chicago Public Schools.

While using PDAs to administer assessments and view data are becoming increasingly popular, few studies have examined the effect they have on teacher practice and student achievement (Brunner & Honey, 2001; Hupert, Martin, Heinze, Kanaya, & Perez, 2004; Sharp & Risko, 2003; Sharp, 2004). Studies that have begun to examine this trend suggest that that these tools assist teachers in thinking more substantively about students' progress.As a whole, the research indicates that the single most powerful affordance of the technology is its ability to support teachers in using assessments to acquire information about students' thinking and learning, and to use the understanding gained to further shape their instructional practice (Brunner & Honey, 2001; Hupert et al., 2004; Sharp & Risko, 2003).Such a strategy places assessment squarely in the center of the classroom where it can potentially count the most.

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The Complex Nature of Change

Another factor influencing the impact of technology on student achievement is that changes in classroom technologies correlate to changes in other educational factors as well. Originally the determination of student achievement was based on traditional methods of social scientific investigation: it asked whether there was a specific, causal relationship between one thing—technology—and another—student achievement. Because schools are complex social environments, however, it is impossible to change just one thing at a time (Glennan & Melmed, 1996; Hawkins, Panush, & Spielvogel, 1996; Newman, 1990). If a new technology is introduced into a classroom, other things also change. For example, teachers' perceptions of their students' capabilities can shift dramatically when technology is integrated into the classroom (Honey, Chang, Light, Moeller, in press). Also, teachers frequently find themselves acting more as coaches and less as lecturers (Henriquez & Riconscente, 1998). Another example is that use of technology tends to foster collaboration among students, which in turn may have a positive effect on student achievement (Tinzmann, 1998). Because the technology becomes part of a complex network of changes, its impact cannot be reduced to a simple cause-and-effect model that would provide a definitive answer to how it has improved student achievement.

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IMPLICATIONS

These findings have implications for every district and school using or planning to use technology. Research on successfully developing, evaluating, studying, and implementing a wide range of technology-based educational programs suggests that the value of technology for students will not be realized unless attention is paid to several important considerations that support the effective use of technology (ISTE, 2002; Byrom & Bingham, 2001; Chang, Henriquez, Honey, Light, Moeller, & Ross, 1998; Cradler, 1997; Frederiksen & White, 1997; Hawkins, Panush, & Spielvogel, 1996; Honey, McMillan, Tsikalas, & Light, 1996; National Foundation for the Improvement of Education, 1996; Pea & Gomez, 1992). These considerations are:

1. Specific educational goals and a vision of learning through technology
2. Ongoing professional development
3. Structural changes in the school day
4. A robust technical infrastructure and technical support
5. Ongoing evaluation

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1. Educational Goals and a Vision of Learning Through Technology

Before technology is purchased or teachers participate in their first professional development session, the educational goals for students should be determined. What do students need to learn, and how can technology promote those learning goals? To answer these questions, the school can convene a technology planning team comprising administrators, teachers, other instructional staff, technology coordinators, students, parents, and representatives of the community. This team first develops a clear set of goals, expectations, and criteria for student learning based on national and state standards, the student population, and community concerns. Next, it determines the types of technology that will best support efforts to meet those goals. The viewpoints of parents and community members are helpful in presenting a broader perspective of skills that students need to succeed after school. In fact, communitywide involvement in determining the school's technology goals benefits the entire educational process (Byrom & Bingham, 2001; Panel on Educational Technology, 1997).

Rather than using technology for technology's sake, the planning team ensures that particular educational objectives are achieved more efficiently, in more depth, or with more flexibility through technology. Cuban (cited in Trotter, 1998) states, "The obligation is for educators, practitioners, and educational policymakers to think about what they are after. Only with clear goals can educators be intelligent about how much they want to spend for what purpose and under what conditions." If there is a clear understanding of the purpose of and type of technology used, evaluating the impact is easier and more valuable. According to Hawkins, Panush, and Spielvogel (1996) and Byrom & Bingham (2001), school districts that successfully integrate technology show a clear and meaningful connection between technology and larger educational goals.

Next, the planning team develops a vision of how technology can improve teaching and learning. Without a vision, lasting school improvement is almost impossible (Byrom & Bingham, 2001). Team members come to consensus in answering the question How Will You Use Technology to Support Your Vision of Learning? Essential to this vision is an emphasis on meaningful, engaged learning with technology, in which students are actively involved in the learning process. Educational technology is less effective when the learning objectives are unclear and the focus of the technology use is diffuse (Schacter, 1999).

The school's vision of learning through technology also emphasizes the importance of all students having equitable access and use of technology—females, special-needs students, minority students, disadvantaged students, students at risk of educational failure, rural and inner-city students. All students need opportunities to use technology in meaningful, authentic tasks that develop higher-order thinking skills. (For further information, refer to the Critical Issue "Ensuring Equitable Use of Education Technology.")

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2. Professional Development

After the educational goals and vision of learning through technology have been determined, it is important to provide professional development to teachers to help them choose the most appropriate technologies and instructional strategies to meet these goals. Students cannot be expected to benefit from technology if their teachers are neither familiar nor comfortable with it. Teachers need to be supported in their efforts to use technology. The primary reason teachers do not use technology in their classrooms is a lack of experience with the technology (Wenglinsky, 1998; Rosen & Weil, 1995). Wenglinsky (cited in Archer, 1998) found that teachers who had received professional development with computers during the last five years were more likely to use computers in effective ways than those who had not participated in such training. Yet teacher induction programs too often focus narrowly on helping new teachers survive the initial year (Fulton, Yoon, & Lee, 2005).

Ongoing professional development is necessary to help teachers learn not only how to use new technology but also how to provide meaningful instruction and activities using technology in the classroom (Ringstaff & Kelley, 2002). "Teachers must be offered training in using computers," notes Sulla (1999), "but their training must go beyond that to the instructional strategies needed to infuse technological skills into the learning process." In successful projects, teachers are provided with ongoing professional development on practical applications of technology.

Teachers cannot be expected to learn how to use educational technology in their teaching after a one-time workshop. Teachers need in-depth, sustained assistance not only in the use of the technology but in their efforts to integrate technology into the curriculum (Kanaya & Light, 2005). Teachers also need embedded opportunities for professional learning and collaborating with colleagues in order to overcome the barrier of time and teachers' daily schedules (The National Council of Staff Development, 2001; Kanaya & Light, 2005). Skills training becomes peripheral to alternative forms of ongoing support that addresses a range of issues, including teachers' changing practices and curricula, new technologies and other new resources, and changing assessment practices. This time spent ensuring that teachers are using technology to enrich their students' learning experiences is an important piece in determining the value of technology to their students. According to Soloway (cited in Archer, 1998), teachers always have been the key to determining the impact of innovations, and this situation also is true of technology.

Besides pedagogical support to help students use technology to reach learning goals, teachers also need time to become familiar with available products, software, and online resources. They also need time to discuss technology use with other teachers. "Transforming schools into 21st century learning communities means recognizing that teachers must become members of a growing network of shared expertise (Fulton, Yoon, Lee, 2005)." Professional collaboration includes communicating with educators in similar situations and others who have experience with technology (Panel on

Educational Technology, 1997). This activity can be done in face-to-face meetings or by using technology such as e-mail or videoconferencing. The effects of introducing technology on teacher professionalization include increased collaboration among teachers within a school and increased interaction with external collaborators and resources.

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3. Structural Changes in the School Day

It is important to build time into the daily schedule allowing teachers time to collaborate and to work with their students. Engaged learning through technology is best supported by changes in the structure of the school day, including longer class periods and more allowance for team teaching and interdisciplinary work. For example, when students are working on long-term research projects for which they are making use of online resources (such as artwork, scientific data sets, or historical documents), they may need more than a daily 30- or 40-minute period to find, explore, and synthesize these materials for their research. As schools continue to acquire more technology for student use and as teachers are able to find more ways to incorporate technology into their instruction, the problem will no longer be not enough computers but not enough time (Becker, 1994).

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4. Technical Infrastructure and Support

Increased use of technology in the school requires a robust technical infrastructure and adequate technical support. If teachers are working with a technology infrastructure that realistically cannot support the work they are trying to do, they will become frustrated. School districts have a responsibility to create not only nominal access to computers and electronic networks but access that is robust enough to support the kinds of use that can make a real difference in the classroom. Teachers also must have access to on-site technical support personnel who are responsible for troubleshooting and assistance after the technology and lessons are in place.

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5. Evaluation

Ongoing evaluation of technology applications and student achievement, based on the overall educational goals that were decided on, helps to ensure that the technology is appropriate, adaptable, and useful. Such evaluation also facilitates change if learning goals are not being met. Administrators can acknowledge and recognize incremental improvements in student outcomes as well as changes in teachers' curricula and practices. Gradual progress, rather than sudden transformation, is more likely to result in long-term change.

Baker (1999) emphasizes that besides being a means to collect, interpret, and document findings, evaluation is a planning tool that should be considered at the beginning of any technology innovation. She adds that the overall focus of evaluation is student learning. Heinecke, Blasi, Milman, and Washington (1999) note that multiple quantitative and qualitative evaluation measures may be necessary to document student learning outcomes. To ensure that evaluation procedures are adequately designed and carried out, administrators and teachers may wish to consult evaluation sources such as An Educator's Guide to Evaluating the Use of Technology in Schools and Classrooms.

All of these issues are important in using technology to improve student achievement. Educational technology is not, and never will be, transformative on its own. But when decisions are made strategically with these factors in mind, technology can play a critical role in creating new circumstances and opportunities for learning that can be rich and exciting. "At its best, technology can facilitate deep exploration and integration of information, high-level thinking, and profound engagement by allowing students to design, explore, experiment, access information, and model complex phenomena," note Goldman, Cole, and Syer (1999). These new circumstances and opportunities—not the technology on its own—can have a direct and meaningful impact on student achievement.

When educators use the accumulating knowledge regarding the circumstances under which technology supports the broad definition of student achievement, they will be able to make informed choices about what technologies will best meet the particular needs of specific schools or districts. They also will be able to ensure that teachers, parents, students, and community members understand what role technology is playing in a school or district and how its impact is being evaluated. Finally, they will be able to justify the investments made in technology.

To help states, school districts, and school personnel plan ways to measure the impact that technology is having on classroom practices and academic achievement, Dirr (2004) in partnership with the Appalachian Technology in Education Consortium and the Mid-Atlantic Regional Technology in Education Consortium, identified the following evaluation strategies:

- Encourage SEAs and LEAs to set aside 10 percent to 15 percent of funds to evaluate their technology grants.
- Provide a model comprehensive plan for states and districts to consider as they design their own evaluation plans to include a statement of purpose, identifies clear objectives, demonstrates valid approaches to research design, and specifies appropriate time frames for analysis and reporting.
- Support efforts to develop shared instruments and sets of common data elements.
- Develop a database of "best practices" for technology programs and applications that have shown to support student achievement in scientifically based research studies.
- Develop a list of highly qualified researchers and evaluators from whom SEAs and LEAs can obtain guidance.
- Explore the development of validated instruments that could be shared across states.

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ACTION OPTIONS: Administrators, the technology planning team, and teachers can take the following steps to improve student achievement through technology.

Administrators and the Planning Team (comprising teacher representatives, technology coordinator, students, parents, and interested community members):

- Review a range of national and state educational standards for student learning (such as those listed in Developing Educational Standards). Seek out content standards that articulate the goals for students to achieve.
- Determine key aspects of national and state student learning standards for the school or district to focus on as educational goals. Involve teachers in this process to ensure that their expertise and opinions are considered.

- Charge cross-disciplinary groups of teachers and technology coordinators with finding new ways that technology can help students to achieve those learning goals.

- Collaborate to create a technology plan for the school. (Refer to the Critical Issue "Developing a School or District Technology Plan.")

- Set one-, three-, and five-year goals for improving student learning through technology.

- Identify specific curricula, practices, skills, attitudes, and policies that can be enhanced through the use of technology to foster significant improvement in the character and quality of student learning. (For example, if the district is interested in improving students' writing performance, word processing with an emphasis on revision and editing should become a salient part of the curriculum across disciplines.)

- Identify classrooms in the district where students are already producing exemplary work using technology; or visit virtual classrooms by viewing CD-ROMs (such as the Captured Wisdom CD-ROM Library produced by the North Central Regional Technology in Education Consortium), videotapes of technology use in schools (such as the *Learning With Technology* videotapes), or Internet sites relating to technology integration in content areas (such as lessons using the Amazing Picture Machine and the Handbook of Engaged Learning Projects). Build a database or other resource that allows the school to share these best practices with school staff and the community in general.

- Be aware of state technology plans, district technology plans, and related policies. Ensure that the school is in compliance.

- Become familiar with factors that affect the effective use of technology for teaching and learning. Learn about research studies conducted in real school settings that describe how technology use is influenced by teachers' experience with technology, adequacy of release time, professional development opportunities, and length of class periods.

- Ensure that teachers are aware of the value of technology for all students, especially those considered at risk of educational failure. (Refer to the Critical Issue "Using Technology to Enhance Engaged Learning for At-Risk Students.")

- Ensure that all students have equitable access to effective uses of technology. Develop strategies for addressing access inequities, strategies for addressing type-of-use inequities, and strategies for addressing curriculum inequities.

- Provide ongoing, extensive, and research-based professional development opportunities and technical support to help teachers use technology to develop meaningful instructional strategies for students. (Refer to the Critical Issues "Realizing New Learning for All Students Through Professional Development" and "Finding Time for Professional Development.")

- Ensure that new, research-based approaches to professional development are consistent with the National Staff Development Council (NSDC) standards for staff development.

- Provide incentives, structures, and time for teachers to participate in highly effective staff development (such as study groups and action research) to help them integrate technology into their teaching and learning.

- Find ways to make appropriate structural changes in the school day and class scheduling to support engaged learning with technology. Consider block scheduling as a possibility.
- Educate parents about new assessment methods that enable teachers and administrators to make judgments about the effectiveness of technology in supporting student learning.
- Use appropriate evaluation procedures and tools to determine the impact of technology use on student achievement based on the learning goals that were set. Consult evaluation sources such as An Educator's Guide to Evaluating the Use of Technology in Schools and Classrooms. Share findings with the community.

Teachers:

- Determine the purpose of using technology in the classroom, as determined by the specified educational goals. Is it used to support inquiry, enhance communication, extend access to resources, guide students to analyze and visualize data, enable product development, or encourage expression of ideas? After the purpose is determined, select the appropriate technology and develop the curricula. Create a plan for evaluating students' work and assessing the impact of the technology.
- Coordinate technology implementation efforts with core learning goals, such as improving students' writing skills, reading comprehension, mathematical reasoning, and problem-solving skills.
- Collaborate with colleagues to design curricula that involve students in meaningful learning activities in which technology is used for research, data analysis, synthesis, and communication.
- Promote the use of learning circles, which offer opportunities for students to exchange ideas with other students, teachers, and professionals across the world.
- Encourage students to broaden their horizons with technology by means of global connections, electronic visualization, electronic field trips, and online research and publishing.
- Ensure that students have equitable access to various technologies (such as presentation software, video production, Web page production, word processing, modeling software, and desktop publishing software) to produce projects that demonstrate what they have learned in particular areas of the curriculum.
- Encourage students to collaborate on projects and to use peer assessment to critique each other's work.
- In addition to standardized tests, use alternative assessment strategies that are based on students' performance of authentic tasks. One strategy is to help students develop electronic portfolios of their work to be used for assessment purposes.
- Ensure that technology-rich student products can be evaluated directly in relation to the goals for student outcomes, rather than according to students' level of skill with the technology.
- Create opportunities for students to share their work publicly--through performances, public service, open houses, science fairs, and videos. Use these occasions to inform parents and community members of the kinds of

learning outcomes the school is providing for students.

- Learn how various technologies are used today in the world of work, and help students see the value of technology applications. (Pertinent online information can be found in the 1998-99 Occupational Outlook Handbook and the Bureau of Labor Statistics Career Information.)

- Participate in professional development activities to gain experience with various types of educational technology and learn how to integrate this technology into the curriculum.

- Use technology (such as an e-mail list) to connect with other teachers outside the school or district and compare successful strategies for teaching with technology.

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IMPLEMENTATION PITFALLS: Educators are not immune to the technology hype that rages all over the country. The pressure to get online or to give students access to the newest technology can be strong. Administrators who feel overwhelmed may make hasty or ill-conceived purchasing decisions. Careful planning for technology use is essential because technology is expensive; few schools have the luxury to change their hardware and software configurations after making a hefty financial commitment. Administrators can work with the technology planning team and consult with computer experts in the community to ensure sound decisions.

Technology purchases sometimes are made without consideration of the school's learning goals. Administrators and teacher-parent organizations seeking to define a meaningful role for technology in their school system need to put their initial energy into defining these goals. Although learning goals will be reviewed and updated based on current research, the effort should be made to stick to the goals and insist that technology purchasing be brought into line with them.

Administrators sometimes fail to budget enough funds for hardware, software, maintenance, professional development, on-site technical support, and the services of an educational technologist to provide support for integrating technology into the curriculum. Careful planning is essential to develop a technology budget that provides for all such factors.

When new technologies are adopted, learning how to use the technology may take precedence over learning through the technology. "The technology learning curve tends to eclipse content learning temporarily; both kids and teachers seem to orient to technology until they become comfortable," note Goldman, Cole, and Syer (1999). Effective content integration takes time, and new technologies may have glitches. As a result, "teachers' first technology projects generate excitement but often little content learning. Often it takes a few years until teachers can use technology effectively in core subject areas" (Goldman, Cole, & Syer, 1999).

Educators may find impediments to evaluating the impact of technology. Such impediments include lack of measures to assess higher-order thinking skills, difficulty in separating technology from the entire instructional process, and the outdating of technologies used by the school. To address these impediments, educators may need to develop new strategies for student assessment, ensure that all aspects of the instructional process—including technology, instructional design, content, teaching strategies, and classroom environment—are conducive to student learning, and conduct ongoing evaluation studies to determine the effectiveness of learning with technology (Kosakowski, 1998).

There may be expectations that technology will solve all the school's problems with student learning and achievement. To be effective, however, technology must be used to promote new learning goals and teaching strategies that are student-centered, collaborative, engaging, authentic, self-directed, and based on development of higher-order thinking skills.

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ILLUSTRATIVE CASES: The following schools and programs coordinated their priorities in technology, made appropriate investments in equipment and professional development, and implemented evaluation procedures to document notable changes in student achievement.

- Hanau Model Schools Partnership
- Union City Online, Union City (New Jersey) School District
- Adventures in Supercomputing

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