DOCUMENT RESUME

ED 471 137 IR 021 860

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TITLE Getting the Most from Technology in Schools. Knowledge Brief.

INSTITUTION WestEd, San Francisco, CA.

SPONS AGENCY Office of Educational Research and Improvement (ED), Washington, DC.

PUB DATE 2002-00-00

NOTE 14p.; Based on "The Learning Return on Our Educational Technology Investment: A Review of Findings from Research."

CONTRACT R302A000021

AVAILABLE FROM WestEd, 730 Harrison St., San Francisco, CA 94107-1242 ($1). Tel: 877-493-7833 (Toll Free); Web site: http://www.WestEd.org. For full text: http://www.wested.org/online_pubs/kn-02-01.pdf/ .

PUB TYPE Information Analyses (070) -- Reports - Evaluative (142)

EDRS PRICE EDRS Price MF01/PC01 Plus Postage.

DESCRIPTORS Academic Achievement; *Computer Uses in Education; Costs; Educational Administration; Educational Finance; *Educational Policy; *Educational Research; *Educational Technology; Elementary Secondary Education; *Technology Integration; *Technology Planning

IDENTIFIERS *Technology Role

ABSTRACT

Spending on computer-based technology in schools continues to grow, based on an expectation that student learning will follow suit, yet, many educators and policymakers are still unsure of how to get the most return on this investment. Research shows that in addition to monetary investments, substantial planning and organization are required if computer-based technology is to enhance student learning. A variety of benefits have been attributed to computer-based technology, yet it has not been easy to pin down its value. Research suggests computer-based technology can have a positive effect on student learning under certain circumstances and when used for certain purposes. In order to inform educators and policymakers who are developing school or district technology plans, this Knowledge Brief addresses the question, "Under what conditions does technology have the most benefits for students?" The lessons learned in this brief are based on a review of various studies. This brief describes the elements educators and policymakers should consider when putting together a thorough and effective technology plan that will help increase academic performance. (Contains 31 references.) (AEF)

Getting the Most From Technology in Schools. Knowledge Brief.

By: Noel White, Cathy Ringstaff & Loretta Kelley

GETTING THE MOST FROM Technology IN SCHOOLS

Written by Noel White,
Cathy Ringstaff, & Loretta Kelley

Spending on computer-based technology in schools continues to grow, based on an expectation that student learning will follow suit. And yet, many educators and policymakers are still unsure of how to get the most return on this investment.

What are the most promising uses for computer-based technology in education? How many computers are optimal in a school? Are they best used in classrooms or in a specialized laboratory? Once computers are in place and the software installed, what's next? What kinds of concomitant investment might be needed in such areas as professional development and technical support? Recent research on computer-based technology in K–12 education sheds some light on these important questions.

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A central theme of the research is that computer-based technology, like the more basic classroom tools of pencil and paper, is a means, not an end. Its power lies in how it is used. Yet, unlike pencil and paper, this technology is both complex and expensive, and less is known about how to fully realize its potential. Research shows that in addition to monetary investments, substantial planning and organization are required if computer-based technology is to enhance student learning.

can use to determine if this "return" is actually worth the "investment." Perhaps, rather than asking, "Is technology worth the cost?" the more important question is, "Under what conditions does technology have the most benefits for students?"

This Knowledge Brief addresses this question in order to inform educators and policymakers who are developing school or district technology plans.

In addition to monetary investments, substantial planning and organization are required if computer-based technology is to enhance student learning.

Researchers have attributed a variety of benefits to computer-based technology: increasing student achievement; improving higher-order thinking skills and problem-solving abilities; enhancing student motivation, engagement, and job preparation; and improving students' ability to work collaboratively. Yet, because measuring such effects is fraught with difficulties, it has not been easy to pin down the value of computer-based technology (e.g., Reeves, 1998; Means, Blando, Olson, & Middleton, 1993; H. J. Becker, personal communication, 2001). There are few reliable, valid, and cost-effective assessments for measuring such qualities as student engagement or the ability to work collaboratively. Furthermore, classrooms are not experimental laboratories where variables can be tightly controlled. Thus, it is not surprising that the impact of technology on learning continues to be debated by educators and researchers alike.

Debates aside, research suggests computer-based technology can have a positive effect on student learning under certain circumstances and when used for certain purposes. However, there is no magic formula that educators and policymakers

Lessons Learned

The lessons in this brief are based on a review of various studies. Our review of the literature on computer-based technology drew primarily on studies that demonstrated impact. We focused on studies that were methodologically sound and particularly those that were longitudinal, showing effects over a long period of time. In this brief, the term "technology" refers broadly to computer-based technology — computer hardware and education software, the Internet, and computer-based multimedia. Based on our literature review, we describe the elements educators and policymakers should consider when putting together a thorough and effective technology plan that will help increase academic performance:

- matching technology with goals;
- including technology as one piece of the puzzle;
- providing adequate and appropriate professional development;
- changing teacher beliefs about learning and teaching;

- providing sufficient equipment: adequate computer-to-student ratio;
- making equipment accessible: classrooms versus computer labs;
- considering computer access at home;
- planning for the long term;
- providing technical and instructional support; and
- integrating technology within the curricular framework.

MATCHING TECHNOLOGY WITH GOALS

Computer-based technology can be used to accomplish a variety of goals. To derive the most benefit from technology, one must be clear about what goals are desired, and then match the technology with those goals.

A helpful way of distinguishing different uses of technology comes from Thomas Reeves (1998), who describes learning "from" computers as different than learning "with" computers. Learning *from* computers occurs when the technology functions essentially as a tutor, structuring the learning process for students. Many drill-and-practice software or computer-assisted instruction programs, for example, lead students through a series of problems or activities designed to develop their skills and knowledge. In these cases, the technology is an instructional delivery system, directing the students through a learning process.

By contrast, students learn *with* technology when they are in a more active role. In this case, students use technology as a tool for problem solving, conceptual development, and critical thinking. For example, students are learning *with* technology when exploring the Internet to carry out a research project and when using email to ask scientists about their work.

Research shows that having students learn *from* computer-based technology can improve basic skills, particularly in subjects such as mathematics and science. Such learning is relatively easy to measure in standardized tests of academic achievement. However, other researchers have found that computer-based technology is most powerful when students learn *with* technology.

To derive the most benefit from technology, one must be clear about what goals are desired, and then match the technology with those goals.

The benefits of learning *with* technology tend to be more difficult to measure. The difficulty results not only from rapid changes in technology, but also because few assessments adequately measure the skills that these kinds of technology enhance, such as critical thinking, other higher-order thinking skills, writing, and problem solving ("Critical Issue," 1999).

Students learning *with* technology develop these abilities in a variety of ways. Current instructional technologies can give visual representation to higher-order concepts, provide tools for data analysis, and help students spend less time doing calculations and more time creating strategies for solving complex problems and developing a deep understanding of the subject matter. Word processors have greatly simplified some aspects of writing, editing, and rewriting. Today's interactive video combines the power of visual presentation with the interactive and information-processing capabilities of the computer (Knapp & Glenn, 1996). With the Internet, students have access to vast amounts of information not found in their textbooks and perhaps unfamiliar to their teacher. Interactions through email have

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helped students improve their reading and writing skills. Email also allows students to collaborate with people from far away. In addition, some students with special needs may be able to communicate better via email and the Internet. Technology, overall, can help teachers accommodate students' varying learning styles (Silverstein, Frechtling, & Miyaoka, 2000). And online sites are available 24 hours a day for additional instructional guidance (Riley, Holleman, & Roberts, 2000).

INCLUDING TECHNOLOGY AS ONE PIECE OF THE PUZZLE

Although technology can support change in education, it will have little impact without accompanying reform at the classroom, school, and district levels. For example, students' standardized test results improved substantially in a school-business partnership called Project Explore in Union City, New Jersey. Researchers who studied this project attribute some of the improvement to students having access at home and at school to technology tools, including email. However, other restructuring efforts were occurring simultaneously, such as a change in the reading curriculum from skill-based to whole language; the use of authentic literature instead of basal readers; block scheduling; extensive staff development; and increased parent involvement. The researchers conclude, "The magic lay not exclusively in the technology, but in the interweaving of a systematic program of education reform with the judicious use of technology-based resources" (Chang et al., 1998, p. 43).

In a study of the Apple Classrooms of Tomorrow project, technology had an enduring, positive impact on student engagement, particularly when the technology was integrated into other aspects of the students' education experience. For example, students were less likely to become bored with computers when teachers used technology as one tool among many in their instructional repertoire. In such classrooms, teachers used computers only when they were the most appropriate tool for completing the assignment, not simply because they were available. Student engagement was more likely to endure in classrooms that emphasized students learning with software rather than from drill-and-practice applications. Also, teachers who took into account individual differences in interest and ability tended to maintain student engagement. Finally, student engagement remained high in classrooms using technology with interdisciplinary, project-based instruction (Sandholtz, Ringstaff, & Dwyer, 1997). Other researchers have reported similar results related to student motivation (Silverstein et al., 2000; Penuel, Golan, Means, & Korbak, 2000).

In IBM's Reinventing Education program, students' reading skills improved through using technology. But the schools also had leadership committed to a school reform plan as well as clear, meaningful education goals. Walt Disney Elementary School in Burbank, California, used technology to improve standardized test scores, but first organized its curriculum and teachers for the effective integration of technology (Reksten, 2000). And in a study of five technology-rich schools (Glennan & Melmed, 1996), goals for student learning were articulated prior to introducing technology into the classroom. As a result, these schools were restructured (e.g., longer class periods and project-based learning), were learner-centered, and had enhanced collegial relationships among adults (e.g., more consultation among teachers about curriculum and individual student learning).

In a paper discussing the cost, utility, and value of technology, Wahl (2000) suggests that organizations should spend 30 percent of their technology budget on equipment and 70 percent on the "human infrastructure" to support ongoing training and technical assistance. Because many schools and districts prefer to spend their limited funds on tangible goods such as hardware and software, it is not surprising that insufficient teacher training is a significant barrier to successful integration of technology into the schools (e.g., Mann & Shaefer, 1997). A lack of sufficient teacher training in technology use at the preservice level exists as well (Willis & Mehlinger, 1996).

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PROVIDING ADEQUATE AND APPROPRIATE PROFESSIONAL DEVELOPMENT

Adequate and appropriate training for teachers is crucial for computer-based technology to have an effect on student learning (Office of Technology Assessment, 1995; Coley, Cradler, & Engel, 1997; Silverstein et al., 2000; Sandholtz, 2001; Heinecke, Blasi, Milman, & Washington, 1999). Teachers who are better prepared to teach using technology and are more knowledgeable about computers use them in a greater variety of ways and are more likely to have their students use technology in tasks that require higher-order thinking (National Center for Education Statistics, 1999b; Wenglinsky, 1998).

In the preservice learning and inservice professional development that do exist, the focus is too often limited to "fundamental computer operation rather than preparation on how to use technology as a teaching tool and how to integrate it across the curriculum" (Sandholtz, 2001). Although teachers need to understand fundamental computer operation, they need to learn much more.

Specifically, teachers need to be taught how to use technology to deliver instruction. Helping teachers learn to integrate technology into curriculum is critical in successfully implementing technology in schools (Sivin-Kachala & Bialo, 2000; Coley et al., 1997; Silverstein et al., 2000; Statham & Torell, 1999). When teachers are learning to integrate technology into their classrooms, the most important staff-development features include

opportunities to try the technology, reflect on their experiences, and collaborate with peers on authentic learning tasks. In essence, the principles for creating successful learning environments for students apply to teachers as well (Sandholtz et al., 1997; Sandholtz, 2001).

In addition to receiving training on how to use technology instructionally, teachers need help in learning how to assess products that students create with computer-based technology (e.g., Penuel et al., 2000). Just as students sometimes focus too heavily on the technology-related aspects of assignments (Henriquez & Riconscente, 1999), teachers can be distracted by the "glitz" of technologically sophisticated student work and lose sight of its "guts" or content.

CHANGING TEACHER BELIEFS ABOUT LEARNING AND TEACHING

If technology is to be used to improve student learning through collaboration, inquiry, and interactive learning, then teachers' beliefs must be consistent with this kind of learning and teaching.

For teachers who believe the lecture-recitation-seat work model of instruction is the best teaching method under all circumstances, even the best professional development on technology will have limited success. Integrating technology into instruction is a difficult, time-consuming process; only those teachers who believe that technology use will lead to significant benefits for their students will undertake the associated challenges.

In the Apple Classrooms of Tomorrow project, a shift occurred in teachers' beliefs about instructional practices as they integrated technology into their instruction and began to see firsthand the benefits of technology use (Sandholtz et al., 1997). Initially, the introduction of technology did not radically change teaching. Instead, technology seemed to serve as a symbol for change, granting teachers a license for experimentation. The use of technology in classrooms initially strengthened the teachers' delivery of text-based curriculum through lecturing, recitation, and seat work. This approach was gradually replaced by more dynamic learning experiences for students, such as collaborative, project-based, interdisciplinary learning. The instructional changes were closely tied to changes in teachers' beliefs about classroom management, learning, teacher-student roles, and instructional practices.

Opportunities for teachers to observe for themselves the impact of technology use on learning and teaching in their colleagues' classrooms can often serve as a strong impetus for changing teachers' beliefs.

Other researchers have drawn similar conclusions about the value of providing teachers with a vision of what can be accomplished using technology, and have noted that teachers who volunteer to be a part of a reform initiative can serve as models and mentors for those who are reluctant to adopt an innovation (e.g., Chang et al., 1998). Opportunities for teachers to observe for themselves the impact of technology use on learning and teaching in their colleagues' classrooms, for example, can often serve as a strong impetus for changing teachers' beliefs and bolster their motivation for undertaking the challenges associated with technology integration.

PROVIDING SUFFICIENT EQUIPMENT: ADEQUATE COMPUTER-TO-STUDENT RATIO

Without sufficient access to technology, even well-trained, highly motivated teachers will not be able to integrate technology effectively into instruction. Although studies are inconclusive about the optimal number of computers per classroom (Mann, 1999), students and teachers are best served if they have convenient, consistent, and frequent access to technology. Statham and Torell (1999) suggest that a 1:5 computer-to-student ratio would assure students "near universal access." Unfortunately, a 1:5 ratio far exceeds what is found in most classrooms. A RAND study (Glennan & Melmed, 1996) of technology-rich schools suggests that the most successful of these schools had a high density of computers and high access to them. In these schools, the expenditure per pupil on computer-based technology was three to five times the national average.

rooms connected to the Internet by a high-speed, direct connection" (Becker, quoted in Soloway et al., 2001). Moreover, there are wide discrepancies in accessibility from state to state and from school to school, with high-poverty schools typically having fewer technological tools (National Center for Education Statistics, 1999b).

Soloway and his colleagues (2001) believe that handheld devices (personal information managers or personal digital assistants) "are the answer" to the challenge of providing adequate technology for K–12 students. Preliminary research with over 2,000 students in a variety of schools around the country suggests that, despite the limitations of handheld devices, they can be effective tools in content areas such as physics and mathematics. Applications in reading, writing, and mathematics are currently available, and more are under development.

Students who had access to computers in their classrooms showed more improvement in basic skills than those who received instruction in computer labs.

While recent surveys about the status of technology in schools suggest that the amount of technology is increasing (Statham & Torell, 1999; National Center for Education Statistics, 1999a), teachers continue to report that lack of access is a significant barrier to technology integration. Many schools have computers that are obsolete (Barnett, 2000; Statham & Torell, 1999). A national survey of technology use revealed that fewer than 20 percent of schools have "at least one computer of any kind for every four students enrolled, . . . [and] at least half of all instructional

MAKING EQUIPMENT ACCESSIBLE: CLASSROOMS VERSUS COMPUTER LABS

In addition to the amount of computer-based technology available, its location affects accessibility (Statham & Torell, 1999; National Center for Education Statistics, 1999a). Computers can be either in a centralized location (such as a computer lab), distributed (in the classrooms), or a combination of the two. In a study in West Virginia that used all three models, researchers found that student outcomes were most improved by the distributed model. That is, students who had

access to computers in their classrooms showed more improvement in basic skills than those who received instruction in computer labs. In addition, teachers who had computers in the classroom reported greater confidence and competence in using them (Mann, 1999; Mann, Shakeshaft, Becker, & Kottkamp, 1999).

Technology projects should be implemented only after administrators and other stakeholders articulate their standards and goals and develop a vision of how the technology is to be integrated into their school or district.

Accessibility is equally important for taking advantage of the Internet. As researchers for the Software and Information Industry Association report, "Classroom connectivity to the Internet was found to be the best predictor of teachers' professional use of the Internet. Furthermore, classroom connectivity in general and, more specifically, connectivity with four or more computers were found to be important factors in predicting whether teachers directed student research involving the Internet" (Sivin-Kachala & Bialo, 2000). Similarly, Henriquez and Riconscente (1999), in a study involving almost 600 teachers in Rhode Island, concluded that a lack of computers connected to the Internet in classrooms was the most significant barrier to the use of the Internet as an important tool for learning.

CONSIDERING COMPUTER ACCESS AT HOME

In addition to investigating the importance of school access, researchers have examined the impact of students' and teachers' use of home computers. Not surprisingly, most have found that home access augments the improvements in student achievement. For example, in a New Jersey study, seventh, eighth, and ninth graders who had sustained access to technology (such as word processing, spreadsheet, and database programs, as well as email and the Internet) at home and at school did significantly better on standardized writing tests than students who had access to similar technology only at school.

In an Indiana study, students who were supplied with home computers and modem access to their school "showed improvement in all writing skills, a better understanding and broader view of math, more confidence with computer skills, an ability to teach others, greater problem-solving skills, and greater self-confidence and self-esteem" than peers who were not provided with these resources (Coley, 1997, p. 4).

Of course, having a computer at home does not necessarily ensure that students are using the computer in ways that will increase their academic achievement. For example, elementary school teachers in the Apple Classrooms of Tomorrow project did not have time to develop appropriate homework assignments using computers. Consequently, in later years, the project continued providing home computers only at the high school site (Sandholtz et al., 1997).

Like students, teachers can often improve their skills with access to a home computer. Teachers typically do not have enough time on the job to learn to use technology, to practice what they

have learned, and to explore further uses of the computer. Teachers who have computers at home have more time not only to learn to use technology, but to become more comfortable with it.

PLANNING FOR THE LONG TERM

As suggested above, technology projects should be implemented only after administrators and other stakeholders articulate their standards and goals and develop a vision of how the technology is to be integrated into their school or district. The most successful schools in IBM's Reinventing Education program, for example, allocated time and other resources for planning how best to use the technology to improve instruction (Trotter, 2001). Moreover, because hardware and software are constantly changing, schools and districts must revisit their technology plan on an ongoing basis and make revisions as necessary (Sivin-Kachala & Bialo, 2000).

Many schools and districts spend most or all of their technology funds on initial purchases of software and hardware, and overlook the fact that replacing, maintaining, and supporting computer equipment will also require money. Unlike many items purchased for schools (e.g., library books, physical education equipment), computer hardware and software, as well as peripheral devices, quickly become obsolete. In some schools, printers sit idle because money was not budgeted to replace ink cartridges, toner, or paper. For this reason, technology costs should be built into school budgets on an ongoing basis (Glennan & Melmed, 1996).

PROVIDING TECHNICAL AND INSTRUCTIONAL SUPPORT

Although adequate access to computer-based technology is a key factor in improving student learning, a major barrier to technology use is the lack of technical support. Even teachers who enjoy using computers will stop if the equipment is unreliable. Many teachers lack adequate trouble-shooting skills — not to mention time — to fix equipment, especially if it breaks in the middle of a lesson. Consequently, effective use of technology requires an adequate school and district infrastructure and must include timely, on-site technical support.

The support teachers need changes as they become more and more proficient in integrating technology into instruction.

Longitudinal research examining teachers' use of technology suggests that the support teachers need changes as they become more and more proficient in integrating technology into instruction. In the early stages of the ACOT project, for example, teachers needed basic technical support as they learned to use new hardware and software. Later, when teachers began experimenting with team teaching and interdisciplinary, project-based instruction, they needed professional development related to alternative student assessment strategies, such as performance-based assessments (Sandholtz et al., 1997). Clearly, as teachers begin using technology for more sophisticated purposes, instructional support is as essential as technical support.

The ACOT project also provides evidence about the importance of principal and administrative support. Principals in participating schools were required to provide time for teachers to plan

together and reflect on their practice; to give recognition for teachers' efforts; and to ensure that teachers had the authority and flexibility to make instructional and curricular adjustments. But not all principals provided this support. The most crucial factor determining whether participating teachers successfully integrated technology into their classroom was the level of support they received from school and district administrators (Sandholtz et al., 1997). These findings are consistent with research conducted by the Office of Technology Assessment (1995).

INTEGRATING TECHNOLOGY WITHIN THE CURRICULAR FRAMEWORK

To use technology effectively, teachers must understand how its use fits into the larger curricular and instructional framework. Researchers at Educational Testing Service (Coley et al., 1997), for example, state that courseware (computer software designed to be used in an education program) should reflect curricular standards and take into account research on how students learn.

According to researchers at North Central Regional Educational Laboratory (Valdez et al., 1999), computer-based technology used in a tutoring capacity is most likely to be effective when there is a match among the software, the objectives of the instruction, students' prerequisite knowledge and skills, and teachers' understanding of the needs of the learners. And in the ACOT study, student engagement remained highest when technology use was integrated into the larger curricular framework, rather than being an "add-on" to an already full curriculum (Sandholtz et al., 1997).

Advocates of technology use in the classroom sometimes cite the importance of developing students' job skills, and teachers often respond by "teaching technology," such as keyboarding or word processing, rather than using it as a tool to teach the curriculum. However, when technology is integrated into the larger instructional framework, students will not only learn how to use the equipment and software, but will also gain content knowledge (Silverstein et al., 2000). Moreover, using technology within the curricular framework can enhance skills that will be valued in the workplace, such as locating and accessing information, organizing and displaying data, and creating persuasive arguments (Sandholtz et al., 1997; "Critical Issue," 1999).

Conclusion

For technology to contribute positively to students' learning experiences, it is important to put together all the many pieces touched upon in this brief: long-term planning, clarifying goals, integrating efforts, coordinating the curriculum, providing ongoing support and appropriate infrastructure, and engaging in appropriate professional development. Perhaps not surprisingly, these conditions for enhancing the value of technology investments are essentially the conditions for improving student learning in general. By putting these pieces in place — and with ongoing attention, funding, and adjustments when needed — computer-based technology can play a significant role in contributing to positive, productive learning experiences for all students.

This paper is based on a longer literature review — *The Learning Return on Our Educational Technology Investment: A Review of Findings from Research* — developed by WestEd's Regional Technology in Education Consortium (RTEC). The longer paper is available at www.WestEd.org/cs/wew/view/rs/619.

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