The Impact of Technology on Education

Why should schools concern themselves with increasing student access to technology? Why should hospitals stock antibiotics? The juxtaposition of these questions is intended to highlight the foundational importance of technology in educating children who are learning in the 21st century. Much like antibiotics have transformed medicine, technology is transforming education.

Even to the casual observer technology is rapidly transforming society and how people, especially children, view the world. The advent of the internet, electronic books, the IPOD, 3G wireless networks, social networks, and the impact of constant connectivity is changing how we accomplish fundamental tasks. Banking and finances, distribution of information and news, shopping, casual reading, research, entertainment, and interpersonal communication, have all been changed markedly by technology. Education is predicated upon communication and the transference of understand of concepts, ideas, and knowledge all impacted by technology.

This paper is a summary of questions and responses regarding the impact of technology upon education compiled from the Web Site for the Center for Applied Research in Education Technology CARET http://caret.iste.org. CARET is a project of the International Society for Technology in Education in partnership with Educational Support Systems. CARET was founded in 2000 with a grant from the Bill & Melinda Gates Foundation. The reader is encouraged to visit the site and explore the volumes of information regarding the impact of technology on education.

Q1: How can technology influence student academic performance?

A: Technology improves performance when used in environments where teachers, the school community, and school and district administrators support the use of technology.

RESEARCH EVIDENCE

Test scores can be increased with implementation of education plans that incorporate applications. Student performance improved on standardized tests in writing and mathematics as part of a broad-based educational change in Union City, New Jersey. Project Explore combined (a) integration of technology with instruction, (b) extensive professional development for teachers, and (c) computer use at home and school with:

- school site leadership
- effective school improvement plans
- a strong emphasis on student creativity and expression of ideas in multiple formats
- an emphasis on different points of entry into a task for students working at different ability levels.

The change effort had the greatest impact on students' standardized-test performance at the K-8 level, where they were in place the longest. (Honey, 1999).

Commitment to technology infusion, which means easy access to equipment, the use of software emphasizing basic skills, and teacher development, can translate to higher test scores. Documented student achievement gains were realized in West Virginia within the context of the

State's eight-year objectives-focused Basic Skills/Computer Education project. Beginning with kindergarten classes in 1990-91, the state provided every elementary school with enough equipment so that each classroom serving the grade cohort of children targeted that year would have three or four computers, a printer and a schoolwide networked file server. Each year, there were successive waves of new computer installations as well as grade appropriate integrated learning software and intensive professional development for teachers (Mann et al., 1999).

Q2: How can technology influence student academic performance?

A: Technology improves student performance when the application directly supports the curriculum objectives being assessed.

RESEARCH EVIDENCE

Technology is most influential when integrated with curriculum and assessment. In a review of studies, the (CEO Forum, 2001) concluded that "technology can have the greatest impact when integrated into the curriculum to achieve clear, measurable educational objectives."

Integration of technology with curriculum and professional growth increases student achievement. Significant student achievement gains for technology integrated with standards were demonstrated by an eight-year longitudinal study of SAT I performance at New Hampshire's Brewster Academy (Bain & Ross, 1999). Students participating in the technology integrated school reform effort (School Design Model) demonstrated average increases of 94 points in combined SAT I performance over students who participated in the traditional independent school experience. In a pioneer "laptop school," where all students and faculty carry portable computers and access a campus network, Brewster's extensive school reform effort involved "rethinking the way we teach, how we build curriculum and the way we support and evaluate faculty" (Bain & Smith, 2000).

A study of a comprehensive effort to integrate technology into schools shows a increase in test scores related to the use of technology. In West Virginia (Mann et al.,1999), curriculum objectives for basic skills development in reading and mathematics were integrated with instructional software. This curriculum was reinforced with teacher instruction and the achievement tests used to evaluate student performance. Gains in student test scores on the SAT-9 (for 950 fifth graders in 18 schools) were attributable to the alignment of the targeted curriculum objectives with the software, teacher instruction and the tests.

In a randomized study in Virginia, use of digital video clips to supplement instruction resulted in increased student achievement (Boster et al., 2002)(Boster et al., 2004). In this case, the video segments were selected from a commercially available library (unitedstreaming[TM]) to align with particular standards in science and social studies addressed by all participating schools in the third and eigth grades. The assessments (pre and post) were likewise specially developed to examine student's knowledge of those standards.

"Intelligent tutor" software that supports curriculum has been shown to improve learning. In

Pittsburgh, an algebra curriculum focusing on mathematical analysis of real-world situations and the use of computational tools is supported by an intelligent tutor software program as part of the regular curriculum for 9th grade algebra. On average, the 470 students in the experimental classes outperformed students in comparison classes by 15% on standardized tests and 100% on tests targeting the curriculum-focused objectives (Koedinger et al., 1999). At this time the algebra curriculum (PUMP) and intelligent tutor (PAT) are used in 70 schools, nationwide.

Teachers observe significant change in student skills and knowledge acquired after their first multimedia project. The Just in Time model for multimedia training enabled university content and instructional design specialists to provide teachers with skills as they were needed for completion of specified products and projects. After student completion of the first multimedia project, teachers reported increased student knowledge in: a) research skills, b) research skills to locate content resources, c) capability to apply learning to real world situations, d) organizational skills and e) interest in the content. (Cradler & Cradler, 1999)

Q3: How can technology influence student academic performance?

A: Technology improves performance when the application provides opportunities for student collaboration.

RESEARCH EVIDENCE

Technology applications that enable student collaboration tend to result in improved achievement. In one study, upper-grade elementary students used a software collaboration tool called Computer Supported Intentional Learning Environment (CSILE) that enables students and teachers to create and post text and graphics to ask questions, search for other students' answers, give feedback on student responses and work and then reformulate their initial answers and questions. These students performed better on standardized tests in reading, language and vocabulary and on measures of depth of understanding, multiple perspectives and independent thought than students who did not use the software (Scardamalia & Bereiter, 1996).

Case studies conducted at nine school sites (urban, suburban, rural) suggest that technology can support student learning through collaborative inquiry. Technology provides realistic, complex environments by furnishing investigative tools and data resources and by linking classrooms for joint investigations (Means & Olson, 1997).

In studies of classroom integration of technology with the National Geographic Kids Network (Newman, 1994), Apple Classroom of Tomorrow (Sandholz et al., 1997), Lego Logo (Lafer & Markert, 1994), and Sky Travel (McLellan, 1994) student collaboration:

- increased the amount of information available because students shared during class time with other teams as well as with their partners.
- enhanced critical thinking because students had to deal with conflicting information and ideas from multiple software programs and online sources in order to solve their problems present through computer simulations.

In another study of student collaboration, when two students worked together on one computer, the student at the keyboard provided more answers during discussion while the other student asked more questions. The social interaction skills acquired through teamwork were found to be important to mastery of certain intellectual skills (Bracewell & Laferriere, 1996).

In a meta-analyses of 16 controlled studies on *Integrated Learning Systems* (ILS), Kulik (2003) concluded that "ILS appear to be more effective when students work in pairs on ILS lessons" (p. 25).

Q4: How can technology influence student academic performance?

A: Technology improves performance when the application adjusts for student ability and prior experience, and provides feedback to the student and teacher about student performance or progress with the application.

RESEARCH EVIDENCE

Software applications that provide feedback about student progress can help them learn physics. Seventh, eighth, and ninth grade physics students used software (ThinkerTools) that enabled them to be aware of where they were in the inquiry process and to reflect upon their own and other student's inquiries. These students were better able to apply principles of Newtonian mechanics to real-world situations than were eleventh and twelfth grade students who had not used the software (White & Frederiksen, 1998).

Students' writing can be improved with word processing software that utilizes writing prompts. However, in a meta-analyses of studies from the 1990's, Kulik (2003) found that prompts appear "to be effective when the computer provides them without being asked; prompting seems to have little value when students must ask the computer for help" (p.42).

A program called DIAGNOSER helps teachers increase student achievement because it assesses students' preconceptions about various phenomena and recommends activities to help students "reinterpret" the phenomena from a physicist's perspective. Teachers also use the program's recommendations to guide instruction. Students who used DIAGNOSER demonstrated levels of understanding of physics concepts superior to that of students who had not used the program (Hunt & Minstrell, 1994).

Online feedback among peers who know one another is effective. Studies have shown that students are more comfortable with and adept at critiquing and editing written work if it is exchanged over a computer network with students they know. And student writing that is shared with other students over a network tends to be of higher quality than writing produced for in-class use only (Coley et al., 1997).

Q5: How can technology influence student academic performance?

A: Technology improves performance when the application is integrated into the typical instructional day.

RESEARCH EVIDENCE

Kulik (2003) found that computer simulations (p.59) and *Instructional Learning Systems* (ILS) (p.25) are effective only when they are integrated into the "regular classroom instruction." In the case of ILS, it is particularly critical to allow students "an adequate amount of time on the programs" (p.24).

The level of technology used by the teacher significantly affected student academic achievement in mathematics in a comparison of fourth and fifth grade teachers and their students. Students whose teachers were high level users of technology in the classroom scored significantly better than did students whose teachers were low level users of technology in the classroom. Teachers who were high level users were differentiated from teachers who were low level users in terms of frequency and extent of use of computers with students, instructional methods used with technology, attitude toward the value of technology for learning, variety of uses of technology, and perception of influence of technology on student learning and behavior (Middleton & Murray, 1999).

It is important that teachers know that students can manipulate the software to achieve a visual solution without conceptual understanding of how the problem is solved. Numerous studies document student understanding of mathematics concepts from using computer-based and -assisted software. Logo programming, computer-assisted instruction (CAI) microworlds, and algebra and geometry software have been effective in facilitating mathematics achievement for elementary, middle, and high school students when teachers are skilled in guiding student activities (Simmons & Cope, 1990, 1993; Hillel, Kieran, & Gurtner, 1989; McCoy, 1996).

Classroom use of computer applications was demonstrated to be more effective than lab use for teaching mathematics. A set of fifth grade students had access to computers with standards-based software in their classrooms, along with teacher-led standards-based instruction (Basic Skills/Computer Education). These students had higher gains overall and in math on achievement tests than did students who experienced the same curricula and technology in lab settings (Mann et al., 1999).

Computer-assisted instruction can be effective when used in laboratories when emphasizing teaching of basic skills. In a study of reading and mathematics achievement among Chapter 1 students in Grades 2-6, experimental groups used Education Systems Corporation (ESC) software in computer laboratories twice per week during a period of one school year. Chapter 1 students who did have access to the computer laboratories demonstrated significant increases in achievement both in reading and in mathematics (Zollman et al., 1989).

Q6: How can technology influence student academic performance?

A: Technology improves performance when the application provides opportunities for students to design and implement projects that extend the curriculum content being assessed by a particular standardized test.

RESEARCH EVIDENCE

Multimedia tends to have long term effects on understanding and retention. In a study of eighth graders using a hypertext/multimedia tool to design their own lessons about the American Civil War, the scores of students using the multimedia tool did not differ from the scores of the control group on a test given at the completion of the lesson. However, when tested one year later by an independent interviewer, the multimedia group displayed elaborate concepts and ideas that they had extended to other areas of history. In contrast, the control group of students remembered almost nothing about the historical content of the Civil War lesson (Lehrer, 1993)

Q7: How can technology be used to generally improve writing skills?

A: The consistent use of word processing improves both spelling and writing, especially when word processing is incorporated into regular assignments and assessments.

RESEARCH EVIDENCE

Word-processing was effective in helping students learn to revise and improve their writing. Spell checkers combined with specially designed instruction were also effective in helping students with spelling problems. Word-prediction software was useful for helping students compensate for severe spelling problems so that their writing is readable (MacArthur, 1995, 1998).

Q8: How can technology be used to improve basic reading skills?

A: Multimedia and video technologies can improve reading comprehension and vocabulary for diverse learners in a variety of settings.

RESEARCH EVIDENCE

Video technology can be used as a tool for facilitating vocabulary acquisition. In a comparative study of 4th, 5th and 6th grade students with learning disabilities, students were randomly assigned to a video instruction group and to a nonvideo group for reading vocabulary and comprehension lessons. Analysis of pre, post and follow-up tests two weeks after the completion of the lessons indicated that students in the video instruction had statistically higher word acquisition scores than those in the nonvideo group (Xin & Rieth, 2001).

The use of video to supplement instruction in core curriculum areas can be an effective supplement that has a high probability of improving learning. A study of UnitedStreaming (TM) video clips with curricula in Virginia showed that there is a high probability of student achievement when:

- video clips are selected to align with the state-adopted curriculum standards.
- the program is used during the time span allocated for instruction related to the standards for which the video clips are aligned
- exam items correspond to each of the curriculum standards being taught
- instructors are trained on ways to use and integrate the video clips with curriculum and instruction. (Boster et al., 2002) (Boster et al., 2004).

Pinkard (1999) found that software with imbedded multimedia literacy activities designed to support early literacy among young African-American students helped "at-risk" students with early reading skills.
ation Technology in Childhood Education Annual, p. 87.

Q9: How can technology be used to improve basic reading skills?

A: The use of computer-assisted instruction focused on phonetic analysis or decoding that incorporates built-in performance assessments to guide the amount of practice needed consistently results in improved reading as measured by standardized tests.

RESEARCH EVIDENCE

A review of 15 years of research on the use of technology to teach or support literacy among students with mild disabilities indicates cautious optimism (MacArthur et al., 2001). Computer-assisted instruction (CAI) has been found to improve phonological awareness and word identification (MacArthur et al., 1995, 1991a, 1991b).

Whole-word feedback was found to be helpful for students with poor phonological awareness. The combination of intensive training in phonological awareness and practice reading with speech feedback was most effective for developing phonological awareness and decoding skills (Wise et al., 1998).

Q10: How can technology be used to improve basic reading skills?

A: Reading comprehension can be improved with programs that utilize content matched to the students' spoken vocabulary.

RESEARCH EVIDENCE

Electronic trade books and other types of software programs for early reading are useful when they incorporate audio clips associated with words on the screen, speech to text, and oral feedback. The e-learning resources may help readers understand connections between their prior knowledge of oral language and written language skills. (Hiebert & Raphael, 1998). For example, the program *Rappin' Reader* provides children with simultaneous word-sound exposure by coordinating a song's soundtrack and visual text on the screen.

Q11: How can technology be used to improve basic reading skills?

A: Multimedia and hypertext can support and expand comprehension strategies for student with a variety fo preferred learning modalities.

RESEARCH EVIDENCE

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Mayer (2001) found learners retained more information when:

- they receive words and corresponding pictures rather than words alone
- corresponding words and pictures are near rather than far from each other
- extraneous words, sounds, and pictures are excluded
- words are presented as narration rather than as text on the screen. (p.185).

Q12: How can technology be used to improve mathematics and problem solving skills?

A: The use of computer assisted instruction focused on basic math skills that incorporates built-in performance assessments to guide the amount of practice needed results in improved learning as measured by standardized tests.

RESEARCH EVIDENCE

Interactive video programs have been demonstrated to increase problem-solving skills. Students across nine states who used Jasper video software as a centerpiece for mathematics instruction for 3 to 4 weeks were compared with students who did not. The comparative research demonstrated that the students in classrooms that used the Jasper video programs were better at complex problem solving (Cognition and Technology Group, 1992).

In a study of the PLATO learning system:

- Math test scores improved for remedial high school students who used PLATO modules containing tutorials, applications and mastery tests, in addition to their normally scheduled math classes. Findings from the use of the PLATO program indicated that:
- Students significantly increased their scores on the Oregon Statewide Assessment Tests (OSAT) between 1998 and 2000
- There was a significant relationship between PLATO modules mastered and scores on the OSAT.

- Students made significantly greater gains on the OSAT than did non-PLATO using students.
- Students were generally positive about using the computer for learning.
- The principal and instructor were generally positive about use of the PLATO materials and felt that “PLATO contributed to learner improvement on the OSAT courses” (Sugar, 2001).

Each PLATO module contained a tutorial, an application, and one or more mastery tests. To move on to the next module required a score of 80% on the mastery test. Students used the PLATO program for 45 minutes every other day and worked at their own pace.

"Intelligent tutor" software that supports curriculum has been shown to improve learning. In Pittsburgh, an algebra curriculum (PUMP) focusing on mathematical analysis of real-world situations and the use of computational tools is supported by an intelligent tutor software program (PAT) as part of the regular curriculum for 9th grade algebra. On average, the 470 students in the experimental classes outperformed students in comparison classes by 15% on standardized tests and 100% on tests targeting the curriculum-focused objectives (Koedinger et al., 1999).

Classroom use of computer applications was demonstrated to be more effective than lab use for teaching mathematics. A set of fifth grade students had access to computers with standards-based software in their classrooms, along with teacher-led standards-based instruction (Basic Skills/Computer Education). These students had higher gains overall and in math on achievement tests than did students who experienced the same curricula and technology in lab settings (Mann et al., 1999).

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Q13: How can technology be used to improve academic performance of students with learning disabilities?

A: Carefully chosen technology applications that provide immediate student feedback and progress monitoring can be more effective than regular group instruction for students with learning disabilities.

RESEARCH EVIDENCE

See evidence under Student Learning: How can technology address the needs of low performing, at-risk, and students with learning disabilities?

Q14: What strategies result in effective instructional applications of technology?

A: Technology's impact on teaching and learning is a function of the extent to which it is systematically incorporated into classroom level lesson or unit plans that describe how available hardware, networks, and content applications will be used to help carry out instructional objectives.

RESEARCH EVIDENCE

Strategies for effective instructional applications of technology "equip all students with the technology of questioning" (McKenzie, 1998). A comprehensive guide to technology planning identifies the pitfalls for schools and districts that purchase hardware and software without adequate funds and infrastructure for staff and curriculum development. McKenzie recommends that education decision-makers pay attention to problem- solving tools ("spreadsheets, databases, word processors, charting programs, outlining programs and multimedia presentation software to support analysis and problem solving" rather than specialized content applications.

Effective technology applications involve a process for continuously incorporating research findings into instructional strategies and curriculum planning. (Cradler & Cradler, 2000) report on the success of the Curriculum Technology Integration Plan (CTIP) process that has consistently resulted in improved student learning directly linked to the professional development and resources supported by participating schools and districts. CTIP is both a results-driven staff development process and a technology integration planning strategy that is based on extensive research. The CTIP is an action-research process that supports continuous assessment at the classroom, school or district level followed by modifications of the instructional setting as needed.

CTIP shares with the Apple Classroom of Tomorrow (Fisher et al., 1996) model the following features:

1. Defining district or national curricular standards. Based objectives for learners.
2. Defining specific tasks students will be doing.
3. Defining interactions between students, technology, and teachers.
4. Describing materials and equipment needed for use by teachers and students.
5. Defining where and how long activities will take place.
6. Identifying assessments to evaluate student work.
7. Identifying a process for informing students, other teachers, parents, and administrators of the extent to which the learning standards are reached or exceeded.

Q15: What strategies result in effective instructional applications of technology?

A: Technology's impact on teaching and learning is a function of the extent to which it is systematically incorporated into school plans that describe very specific ways that technology is integral to curriculum, instruction, and school administration.

RESEARCH EVIDENCE

An overall vision of technology integration (e.g., a general vision statement) can provide a broad conceptual framework that directs specific school and classroom-level applications of educational technology. (Hayes, Schuck, Segal, Dwyer, & McEwen, 2001) examined the school and classroom-level integration of computer-based educational technology at six Australian schools. They concluded that a clearly articulated vision of technology integration was a fundamental component of an effective integration program. Such general vision statements should provide an articulated overview of the technology integration program, specify the overall goals to be achieved, and should provide adequate direction for specific classroom applications of computer-based educational technology. Examples of overall integration program goals cited by Hayes et al. include:

- Information technology is employed as an integral component of the overall education process, and is not confined to use in a particular discipline.
- Teachers and staff will increasing their understanding and use of information technology through ongoing professional development and training.
- Information technology will help link teachers to the overall world-wide community of educators, thereby providing increased access to peer support and advice.

Staff development specific to the application of software for building basic skills in reading, writing, and mathematics was an important factor in the success of the Basic Skills/Computer Education technology project. The eight-year technology project in West Virginia (Mann et al., 1999) involved the planning and systematic implementation of technology integration throughout the state. Each year from 1990-91 onward and beginning with kindergarten, West Virginia provided every school with enough equipment so that each classroom serving the grade cohort targeted that year might have three or four computers, a printer, and a school-wide, networked file server.

In addition, intensive professional development was provided on the uses of the IBM and Jostens learning software. Both students and teachers experienced a significant amount of new equipment and software that related directly to basic skills' instruction in reading, writing, and mathematics. Each software package was closely aligned with national standards and the instructional goals of West Virginia. Teachers were given intensive preparation in the uses of the software and the instructional strategies with which it was to be used.

Q16: What strategies result in effective instructional applications of technology?

A: Technology's impact on teaching and learning is a function of the extent to which it is systematically incorporated into instructional planning that includes curriculum and technology and teaching strategies matched to the students' learning needs.

RESEARCH EVIDENCE

An intelligent tutoring software program (PAT) enhanced learning outcomes in an urban high school district. Critical to the success of the Pittsburgh Urban Mathematics Project (PUMP) was the client-centered design approach that matched level of student expertise in curricular objectives and classroom teaching with an intelligent tutor, PAT. The algebra curriculum used as a regular part of the 9th grade classes focused on mathematical analysis of real world situations and the use of computational tools. In a laboratory setting, PAT engaged students who usually present difficulties in normal classrooms and accommodated a large proportion of student questions, thus enabling the teacher to give more individualized help. On average the 470 students in the experimental classes outperformed students in comparison classes by 15% on standardized tests and 100% on tests targeting the PUMP objectives (Koedinger et al., 1999).

An intervening process that supports curriculum objectives and enables educators to consciously assess student needs is an effective instructional tool. The Curriculum Technology Integration Plan (CTIP) facilitates the incorporation of research findings into ongoing refinement of curriculum based on changing student needs and curriculum standards. (Cradler & Cradler, 2000) used the CTIP process in a study of Department of Defense schools in Italy. Findings demonstrate how the CTIP process led to the effective use of technology for meeting the particular instructional goals. Results consistently show that the CTIP:

- Enabled teachers to effectively plan for more instructionally relevant technology use.
- Helped teachers to link outcomes to assessments and then target related activities and resources.
- Facilitated classroom level conceptualization of student assessments.
- Served as a vehicle to engage teachers in thinking about the most effective applications of technology to meet the specific needs of their students.
- Promoted conceptualization of new teaching strategies that incorporate technology.
- Offered a process for classroom level evaluation of the impact of specific courseware in a particular instructional context.
- Facilitated the linking and integration of classroom applications of technology with the School Improvement Plans.
- Provided a classroom level performance-based assessment of the impact of particular courseware on student learning.
- Stimulated the development of expanded projects and programs by teachers.
- Provided valuable information about effects of specific technology application strategies that otherwise could not have been obtained.

Q17: How can technology influence student academic performance?

A: Technology improves performance when the application provides opportunities for students to design and implement projects that extend the curriculum content being assessed by a particular standardized test.

RESEARCH EVIDENCE

Multimedia tends to have long term effects on understanding and retention. In a study of eighth graders using a hypertext/multimedia tool to design their own lessons about the American Civil War, the scores of students using the multimedia tool did not differ from the scores of the control group on a test given at the completion of the lesson. However, when tested one year later by an independent interviewer, the multimedia group displayed elaborate concepts and ideas that they had extended to other areas of history. In contrast, the control group of students remembered almost nothing about the historical content of the Civil War lesson (Lehrer, 1993)

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