

EDUCATION FOR AN INFORMATION AGE
Teaching In The Computerized Classroom, 7th edition

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

Chapter One

Technology Use in Teaching and Learning: What's the Return on Investment?

The greatest wrong, the greatest treason,
Is to do the right thing for the wrong reason.

T.S. Elliot (1888-1965)
Murder in the Cathedral

In time I will utter the truth of my plight.
I will remember the people who helped me.
I cannot do this without help.

Autistic child
(communicating using computer-based technology)

LEARNING OUTCOMES

This chapter reviews research and other published reports that examine the effectiveness of computer-based teaching and learning. The objective is to justify the expense in time and money incurred by schools in the acquisition of instructional technologies and requisite user skills.

Teachers who have successfully incorporated the computer and related technologies into the teaching and learning process have come to the conclusion that it can add significant value to teaching and learning *when it is integrated thoughtfully by the teachers, with strong commitment and support from school administrators at all levels*. Absent this *thoughtful integration and strong commitment and support from administration*, investment in computer-based technologies for teaching and learning will yield little or no return.

The material covered in this chapter, coupled with the evidence that teachers gather from their own experience using the computer in the classroom, is of great value because it should provide a rationale for requests made to foundations and local, state, or federal government agencies for grants and other support of technology-assisted learning. To quote Bailey (1992): "[The] response to the question: 'What does research say about the impact of technology on education?' has a direct bearing on how school board members, parents, teachers, and students view and support technology."

Teachers are not just teachers; they are fund-raisers, too. They need to learn how to write proposals requesting financial support for their work in the classroom. Chapter 12 will cover the whole process of writing grant proposals, which will be successful depending on whether or not the proposal convinces the providers of financial support that they are likely to get a worthwhile return on their investment. Hence the need to be familiar with studies that support the effective incorporation of instructional technologies into the curriculum.

This chapter thus will examine the following topics:

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

- Sources for Research and Other Findings
- What General Conclusions Can Be Drawn from the Research?
- In What Ways Does Digital (Computer-Based) Technology Enhance Teaching and Learning?
 - When used effectively, the computer is a valuable tool in support of learning
 - When used effectively, the computer is a valuable tool in support of teaching
 - When used effectively, the computer is a valuable tool in support of children's socialization
 - Computers and related technologies enable children with disabilities to integrate successfully into the educational system
 - Software that is well-designed to support learning enables a teacher to duplicate excellence
- Summary of research outcomes
 - The Three R's
 - Science
 - Social studies
 - Computer-assisted collaborative learning
 - One-to-one computing
- Why Is It Taking So Long for Schools to Change?
- Computer-Integrated Teaching and Learning: The Ten Pillars of Success

This is by no means an exhaustive list of those instructional technology application areas that have been researched in any depth. But it is likely to be of interest to those preparing for, or already engaged in, teaching K-12 because they address broad-based topics that relate to key areas of responsibility within the educational process.

INTRODUCTION

The goal of this book is to help teachers integrate computer-based technology into the educational curriculum in such a way that it improves learning. The significant investment of time and effort, not to mention money, in pursuit of this goal is a relatively recent phenomenon in schools. Computers first started appearing in K-12 classrooms in the late 1970s. Since then, huge sums of money have been spent to provide schools with computers and computer-related equipment. Teachers worldwide, but especially in the wealthier nations, are trained in the use of instructional technologies for teaching and learning.

Such an investment presupposes a consensus that the myriad applications of this technology currently flooding the educational marketplace are an improvement on tried and true teaching methodologies. Is this the case? Dickson (1984) quotes Joseph Weizenbaum, Professor of Computer Science at the Massachusetts Institute of Technology, who cautions: "Everyone agrees that in principle computers are powerful, but too often teachers ... find they are following a common scenario: First you get the hardware, then you get the software, then you train the teachers, and only then do you start trying to work out what you are going to do with it all."

[The International Society for Technology in Education \(ISTE\)](#), in 1998 published an online report titled: "Our Educational System Must Produce Technology Capable Kids" (ISTE, 1998). These

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days, however, one hardly needs an educational system as such in order to produce technology-capable kids. Children are now technology-capable, for the most part, by the time they reach adolescence without much help from schools. They use information technology for "problem-solving and decision-making" to a much more sophisticated degree than most of their parents. They are "creative and effective users of productivity tools" such as word processors and, increasingly, of graphics, spreadsheet, presentation and database software, too. They use e-mail, instant messaging, and text messaging as a matter of course, communicating in writing far more extensively than most adults.

The issue of raising children who are technology-capable is rapidly becoming a non-issue for schools as technology becomes an integral part of the infrastructure of modern life, starting in the home. By the time children go to school, many are already more technology-savvy than their teachers. Most, if not all, children in the wealthier countries of the world soon will come to school with a wireless computer/communications device small enough to fit easily into their backpack and which, using cellular technology, will give them 24/7 access to all the online learning services they might need.

Close to two million K-12 teachers in the U.S. will retire by the year 2010 (ISTE, 1998). This is an extraordinary number when one considers that there are only a little over three million U.S. teachers in the total workforce! This represents a great opportunity for effecting change in schools, an opportunity which ISTE addresses very well in another report: "Will New Teachers Be Prepared to Teach in a Digital Age?" (Milken Exchange/ISTE, 1999,1). In her foreword to the report, Cheryl Lemke, Executive Director of The Milken Exchange, puts it well when she says: "Today's students live in a global, knowledge-based age, and they deserve teachers whose practice embraces the best that technology can bring to learning."

SOURCES FOR RESEARCH AND OTHER FINDINGS

What is the research that indicates that computer use in schools is effective? There are many resources available to help answer this question. For example, Apple Computer, Inc. (1990) made available in electronic form an extensive review of research done between 1980 and 1989 to assess the impact of computers on K-12 education. The project was managed by Dr. Lyn Allen of Apple Computer, Inc. and edited by Dr. Dan Gibbs, former Superintendent of the Fort Myers, Florida, school district. The review does a good job of directly or indirectly summarizing the findings of several hundred published studies.

The findings of the Apple-sponsored project, summarized in this chapter, are to a large extent corroborated by similar reviews (OTA, 1988, 1994, Kinnaman, 1990) carried out by more manifestly disinterested parties.

David Dwyer (1990, 1994), Director of the [Apple Classrooms of Tomorrow \(ACOT\)](#) program and a recognized expert in the application of technology for learning, has led a longitudinal research study, begun in 1985, which has collected and analyzed data from technology-infused classrooms. The objective has been to "investigate how routine use of technology by teachers and students would affect teaching and learning."

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[The Milken Family Foundation Education Technology Initiative](#), formerly The Milken Exchange, in collaboration with ISTE, conducted extensive research to evaluate technology's value for teaching and learning. The report, published in 1999, examined learning technology issues in K-12 education, in particular whether or not technology use is effective in improving learning.

A more recent report entitled: "Effects of Using Instructional Technology in Elementary and Secondary Schools: What Controlled Evaluation Studies Say," (Kulik, 2003) has reviewed research studies of technology applications in elementary and secondary schools published between 1990 and 1999. Kulik examined these studies as to their findings in the areas of reading, writing, math and science instruction. In general, the conclusion of the SRI study is that "the literature is too uneven for sweeping conclusions about the effectiveness of instructional technology." However, solid conclusions may be drawn about specific aspects of technology's value as a tool for learning.

This is particularly true of writing, a skill fundamental to the whole learning process. Writing, like speech, is a medium of communication, and effective communication is key to so many life skills. If technology can help improve students' writing abilities, then technology has an important place in schools. The studies examined by Kulik found benefits of technology in other areas of K-12 education as outlined later in this chapter.

Furthermore, articles are published week after week, in journals and magazines devoted to sharing the results of ongoing research, along with anecdotal accounts of successful application of technology in the classroom. One of the more significant publications is the [Journal of Research on Technology in Education](#), published quarterly by ISTE.

A study sponsored by [The Center for Research in Educational Policy \(CREP\)](#) at the University of Memphis (Lowther et al., 2003) compares the relative benefits of different degrees of technology infusion in 5th, 6th, and 7th grade classrooms. The study sets out to determine whether a 1:1 computer-to-student ratio (using laptops made available to the students 24 hours a day, 7 days a week) would promote superior learning in the areas of writing and problem-solving as compared to control classrooms where there were 5+ computers per class. The results from this study, along with a research synthesis of the implementation and effects of one-to-one computing initiatives (Bonifaz, Zucker, 2004, and Penuel, 2005, 2006), are included in this chapter in the summary of research outcomes.

WHAT GENERAL CONCLUSIONS CAN WE DRAW FROM THE RESEARCH?

When John Vincent Atanasoff invented the electronic digital computer in 1939, he did so to meet an educational need: to free his doctoral students in the Physics department at Iowa State University from the tedium of doing math so that they could concentrate their academic time and effort on problems associated more directly with physics (Mollenhoff, 1985). But it was not until the late 1970s that computers began appearing in K-12 classrooms, and not until the late 1980s that they were present in sufficient numbers to make any kind of appreciable difference.

"The mark of fertility in a science," according to Jean Piaget (1926), "is its capacity for practical application." Can the computer as a tool for teaching and learning be practically applied in schools? What evidence is there that computer-based teaching tools make a difference in the

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learning process? Is this merely another pedagogical fad destined to come and go like so many others? How well have these systems been designed? Do they reflect the wisdom of educational philosophies born of centuries of cumulative educational experience?

Has the research been done to answer these important questions? The answer is Yes—to some extent at least; though much more research needs to be done (Riel, 1994). Milken Exchange/ISTE (1999, 2) reports that "Research on the impact of technology on learning is in its infancy, though we are beginning to see solid work emerge."

The many studies that *have* been done indicate that specific aspects of the learning process can be significantly augmented by computer-based educational technologies. However, as Selfe (1992) points out, computer-based teaching and learning presents a whole new set of pedagogical and logistical realities that will need to be thought through before technology can be integrated into the curriculum in the best possible way.

Kinnaman (1990) and Tierney (1992), too, remind us that much of the research that has been done might have been more impressive if it had been conducted in other than traditional learning settings. Connected to online resources such as the World Wide Web, the computer puts the student in a learning environment that spills over outside of the classroom into everyday life. For a growing number of students, the classroom—the locus for learning—is not necessarily in school. Ready access to online and offline computer-based technologies provides opportunities for learning more or less any time and anywhere. So we do need to study what learning occurs in non-traditional settings.

Judy Salpeter (1998), Editor-in-Chief of *Technology and Learning* magazine, interviewed eight of the leading research experts in this field of educational applications of technology. Whether or not the use of technology in education is effective, she notes, is "an issue that's far too complex to yield a simple answer." We have to decide "what types of technology, with which types of students, under what conditions, lead to best results." It will be instructive to examine what her interviewees had to say.

For example, from her interview with Henry Jay Becker, sociologist and professor of Education at the University of California, Irvine, it is clear that technology works well as a tool in constructivist learning environments where the learner, alone or as a member of a team, is able to delve into larger, more complex projects. Becker's review of the research nonetheless leads him to recognize the proven value of technology when applied to the learning of basic skills in traditional settings.

Larry Cuban, professor at Stanford University and a former high school teacher, is critical of those who advocate technology use in schools primarily for the purpose of preparing students for gainful employment in a computerized world. For Cuban, this is a classic example of "doing the right thing for the wrong reason." It leads to schools investing heavily in technology infrastructure without significantly, if at all, changing the way schooling is done. Cuban, however, like Becker, recognizes that technology can affect teaching by promoting a constructivist approach. Indeed he is optimistic in this regard.

Salpeter also interviewed David Dwyer, vice president for advanced learning technologies at Computer Curriculum Corporation (CCC). Prior to joining CCC, he directed the Apple Classrooms of Tomorrow (ACOT) research program—a program praised by Cuban for readiness

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to "think outside the box" of traditional schooling when infusing learning environments with computer-based technologies. The outcomes of the ACOT program demonstrated the benefits of computer use for both traditional and non-traditional learning modalities. Indeed, quantitative studies conducted at sites sponsored by the ACOT program showed, time and again, that "it takes about 30 percent less time to learn the same things with help from the computer."

Another of Salpeter's interviewees was Cheryl Lemke of The Milken Exchange on Educational Technology. This organization has as its mission to examine and report on learning technology issues in K-12 education. Lemke points out that educational research into the effectiveness of technology use in education should be asking better questions, such as "What is the set of conditions for technologies in schools that optimize learning?" Her point is that learning can be "energized through the creation and effective use of technology and communications."

The Milken Exchange conducted public opinion polls about technology use in education which indicated that Americans were worried that schools in the United States were moving too slowly in implementing technology, that schools which were not well-equipped put their students at a disadvantage over those that were, and that they were willing to have their own taxes dedicated to funding investments in education.

Summarizing the outcomes of the study conducted by The Milken Exchange (Milken Exchange/ISTE, 1999, 2), Lemke concluded that, under the right set of circumstances:

- technology and communications can accelerate, enrich and deepen basic skills;
- technology can be a great tool for motivating and engaging students;
- technology in schools can be a wonderful link between academics and emerging practices in a host of professional fields, so to speak taking science out of the laboratory and out into the field of every day life;
- technology can dramatically increase the viability of students in the work force, the skills acquired making them more employable and professionally productive;
- technology can strengthen teaching, providing teachers with a powerful learning tool which also promotes individualized instruction;
- technology can be a catalyst for change in schools by prompting teachers to rethink how they do education by rethinking their whole role in the classroom when they need no longer think of themselves as the provider of information content, but rather as the facilitator of learning in an already information-rich online environment.

Barbara Means, vice president of the Policy Division and a member of the Center for Technology in Learning at SRI International in California, cautions school districts against using standardized tests to measure the effectiveness of a technology program, if only because of the difficulty of interpreting results without a rigorous research endeavor. In this, she is echoing the views of Raymond Rose, also interviewed for *Technology and Learning* magazine, who criticizes the return on investment (ROI) mentality of politicians who want to see outcomes measured by standardized test scores. Instead, Means recommends assessing students by measuring outcomes against the question: "What is it we want students to know and be able to do?" In other words,

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

while objective standards are all well and good, unless technology is specifically used to promote learning of the standards, its use cannot be measured against them.

Rose, director of the Educational Technology Lab at The Concord Consortium in Concord, Massachusetts, further believes that we should be using technology to enable learning that could not happen otherwise. Such learning might include something as simple as using technology tools for graphing data or conducting dangerous science experiments using computer simulations. What added value does technology bring to the classroom? That is the question that needs to be asked and answered when assessing technology's impact in education.

The next of Judy Salpeter's interviewees, Saul Rockman, has been involved in instructional technology research for many years. In study after study, he says, there have been "substantive changes in teaching and learning when technology is used in appropriate ways." This includes infusion of technology into a learning environment such that it is so pervasive that it becomes a part of the school culture. The ultimate example of this would be where a school provides laptop computers for every student in the school, along with wireless access to online services. Teachers and students are thus able to operate within the context of a reality where neither the classroom, nor the learning process, is any longer confined within the four walls of any single location. The outcome: a substantial reduction in lecturing and an increase in project-based instruction and cooperative learning amongst students. However, Rockman emphasizes the importance of the teacher's role even in a technology-rich environment such as this. Students need feedback and guidance in all aspects of learning, especially early on, whether technology is used or not.

Rockman also notes the increase in parent involvement in education where communications technology is used to close the gap between the home and school. But above all, Rockman pleads for teachers to be given time and support to integrate the technology into their teaching, a theme to which we will return again and again in this book.

The last of Salpeter's interviews was with Jay Sivin-Kachala, vice president of Interactive Systems Design, Inc., whose "Report on the Effectiveness of Technology on Schools, '90-'97" reviewed 219 research studies to assess technology's impact on learning in all K-12 subject areas and age groups. This report was also reviewed for The Milken Exchange/ISTE study (1999,2) which analyzed "the five largest scale studies of educational technology to-date." In his interview, Sivin-Kachala brushes aside the question as to whether or not we should be using technology in schools, but rather reiterates the findings of Rose and Means that we have to ask "Under what conditions is technology valuable?" Specifically, Sivin-Kachala's review of the research showed interactive video, CD-ROM storybooks, computer-based drill and practice and tutorials to be powerful instructional tools. Higher order thinking skills were also shown to be taught better with computers, all other things being equal. This latter finding was predicated on the use of the right assessment tools—performance-based assessment, not simply standardized tests. Students using computer-based tools designed to develop higher order thinking skills were able to score as well as non computer-using groups in standardized tests. Computer-based learning thus *added value* to the normal classroom instruction.

A common theme emerging from all these studies is that teaching is key. The better the teacher is trained in the use of technology for instruction, the more effective the computer-based learning will be. Sivin-Kachala concludes his interview by saying that "it's not just the technology that

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

determines the quality of a learning situation; it's the whole mix – what the class does before they use technology, what the teacher does while students use technology, how the students are grouped, how prepared students are for technology-based learning experiences, and what the class groups or individual students do as a follow-up to using the technology." All these variables need to be considered and are controlled by the well-trained and well-prepared technology-using teacher.

IN WHAT WAYS DOES DIGITAL (COMPUTER-BASED) TECHNOLOGY ENHANCE TEACHING AND LEARNING?

The following sections discuss ways in which the suitably-integrated computer can contribute to quality outcomes in the classroom. Useful further discussion would be for you to brainstorm on this subject to come up with other ways in which such outcomes are enabled by computer-based teaching and learning.

When used effectively, the computer is a valuable tool in support of learning

During the course of this text, we will examine various specific types of computer-based learning systems that take different approaches to helping children assimilate knowledge. These include drill and practice programs, tutorials, simulations, technology-facilitated collaborative learning, distance learning, integrated learning systems (ILS), and Internet-based learning in hypermedia and multimedia environments.

Networking—the linking of computers over communications lines—is opening up an ever-expanding world of learning opportunities for students, teachers and administrators alike. More and more states have established networks to facilitate communication between school administrations and a central state administrative office. States are also realizing the benefits of size-related clout when negotiating with vendors such as online database or telecommunications providers for statewide information services. This is true, for example, in Ohio where the Department of Education has negotiated with computer software and hardware vendors on behalf of the state's public school and university systems.

Nationwide, schools can now take advantage of federally-funded communications highways—the so-called National Information Infrastructure (NII)—which are encouraging data sharing as never before with the potential for significant individual information gain. The Internet, in particular, is an ever-expanding data resource with increasing significance at all levels of education. Not only can students tap the Internet for encyclopedic content from A to Z; they also can use the Internet to communicate with other students, as well as with teachers and other subject-related "experts" both locally and around the globe. We will return to this theme at various points throughout this text, but especially in chapter 8 where the focus will be on distance learning and the Internet.

The best school districts are making this resource available to students at every age level—appropriately supervised, of course. Netiva Caftori (1994) advises, based on her research, that "software systems should come bundled with the teacher." Students, even at the college level, often need the teacher to help them manage the learning process and get the most out of learning opportunities, with the goal of fostering a structured, goal-oriented, quality education. After all,

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

as Barbara Foster (2000) put it so well, "The teacher's goal is always to design learning experiences that will help the students succeed."

This new online, interactive modality for learning is leading to interesting changes in the way education is done (Riel, 1994). This is a subject that will be discussed further at various points throughout the text. Lemke (2000) notes that digital media are a "reflection of our society—they are instantaneous, interactive, up-to-date, just in time, often visually stimulating and accessible round the clock." Digital media also are a fast-paced highway for new discovery in all areas of knowledge. Dedicated students at the highest levels and in all academic disciplines are patiently pursuing their investigations of current understanding, from fractals to foreign policy, quicksands to quickfreeze, shrimps to Shakespeare, video compression to volleyball, and so forth.

This reality of our modern world inexorably must be reflected in our schools if those schools are not to become anachronistic. Lemke therefore advocates that schools should "create a learning culture which actively engages students in relevant, meaningful work within the study of the vast knowledge base that is constantly being reshaped by emerging technologies."

When used effectively, the computer is a valuable tool in support of teaching

Technology-aware teachers use the computer to prepare and produce printed (hard copy) and screen-displayed (soft copy) teaching and learning materials of all kinds, whether word processed documents, presentation materials, still-image and video graphics, or database records.

Preparation of syllabi, schedules, and classroom materials can be more efficiently and professionally produced using the computer. This is especially the case when, as is more and more likely the case, the printer is a high quality device such as a laser printer. It is anachronistic today to use the typewriter for this kind of work. Having said that, it is not a bad idea to know where you can get access to a typewriter on the rare occasion when you might need one!

Word processors, spreadsheets, databases, and presentation software, as well as special-purpose classroom administration systems now available free of charge on the web (at locations such as <http://www.schoolonline.com>), can streamline data presentation, record-keeping, and availability of school-related information. All this, however, is predicated on the teacher being well-organized in the first place. It is a well-demonstrated axiom that the computer is only as organized as the person using it!

Savvy teachers also are taking advantage of the Web to provide learning modules and other resources which virtually extend, beyond the classroom, their influence over their students' education. We will discuss these issues further in chapters 7 and 8 of the text which discuss networks (chapter 7) and online systems such as the Internet (chapter 8).

Students are the beneficiaries of teacher use of computer-based technology to assist in classroom instruction. They are more likely to be given necessary, valuable, timely and accurate feedback on their progress, along with pointers (hyperlinks or hotlinks) to locations "out there" where they can discover or construct the information that will serve them all their lives.

When used effectively, the computer is a valuable tool in support of children's socialization

This can come about not simply by exposing children to computer programs that help them learn about themselves and their world, but also by fostering cooperative or collaborative learning. The

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

computer is a tool to share. It is fascinating to observe small groups of children gathered at the computer working together on a writing project where all the work is captured electronically. Each student brings his or her own special abilities to the project. Students unhesitatingly call on their teammates to help them with knowledge or skills that they lack. This is collaborative learning at its best. Howard Gardner (2000) acknowledges that his theory of multiple intelligences has particular relevance in a classroom where the special talents of each individual student are allowed to flourish in this way.

Computers and related technologies enable children with disabilities to integrate successfully into the educational system

Chapter 13 (Computers, Education, and Society) discusses some of the enabling systems that have been developed over the last ten to twenty years. These systems make it possible for the physically-challenged to function independently in society. Advances in enabling technology have accelerated since the early 1990s to the point where today children with almost any physical disability can be provided with computer-based systems which will allow them to communicate, do research, collaborate with their peers, learn, and contribute as effectively as other children in and out of the classroom setting.

Thompson (1996) goes further in suggesting, based on his personal experience working with children with disabilities, that such children actually have an academic advantage because their disability ensures that they have early access to computer-based education. In Pennsylvania, for example, it is mandated by state law that children who are defined as disabled have a guaranteed sufficiency of support, including whatever technology is available to help them enjoy the same educational benefits as non-disabled children.

Software that is well-designed to support learning enables a teacher to duplicate excellence

There are more and more examples of educational software recognized as pedagogically sound. Many teachers are now using productivity software—word processors, database management systems, spreadsheets, communications software, drawing tools, along with other administrative tools for handling grades, attendance, and so forth—to manage the whole process of teaching and learning. They are creating excellent learning materials that, because they are produced in electronic (digital) form, can easily be shared with their colleagues everywhere. Well-designed and integrated materials such as these support successful learning environments for children, thus duplicating excellence when they are made available to all.

Taking this idea one step further, in chapter 11 we will discuss authoring systems. These products help take the creation of learning systems out of the hands of technologists and into the hands of the teachers themselves. Innovative teachers thus are able to share their expertise—duplicating excellence—by developing lessons (and tutorials, learning modules, simulations, and so forth) that incorporate an ever-expanding array of computer-based teaching and learning aids.

At one time or another all teachers have those magic moments when they touch the hearts and minds of their students and thus, as the saying goes, "touch the future." But even the best teachers in the world find it difficult to operate at their best all the time. We all have our professional ups and downs. As long as we have to rely solely on our own devices to manage the educational process, we inevitably subject our students to something of a roller-coaster educational

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

experience. Thoughtful integration of appropriate computer-based learning can take some of this pressure off teachers, enabling them to provide, from their own stock of teaching experience as well as that of others, consistently excellent learning experiences both in their classrooms and in their students' homes.

In recent years we have seen a truly amazing growth in web-based services for educators where dedicated teachers, education organizations, local, state and federal government entities, and even companies, have invested time and effort (and money) in developing rich portals or gateways to learning resources that are, for the most part, freely available for teachers and students to use. One of the oldest of these organizations is ERIC (Education Resource International Clearinghouse). But ERIC is no longer (as of December 2003) supported by the US Department of Education. Fortunately, other organizations are taking up the slack. A selection of these may be reviewed in the [EdIndex](#)—a web resource maintained by the authors of this book with [links to dozens of such websites](#).

SUMMARY OF RESEARCH OUTCOMES

The Three R's

Reading, Writing and Arithmetic, since the early 19th century at least, have been hailed as the basic ingredients of education for literacy¹ at the elementary level. The vast majority of children are born equipped with the intellectual prerequisites for literacy—the ability to read, write and handle enough math to cope with the demands of the contemporary world. Ensuring that every child has the opportunity to become literate is still largely the role of primary schools worldwide.

What evidence is there that computer technology can help children learn to read, write, and do math?

As you review the conclusions that follow, bear in mind that learning outcomes often complement each other. For example, when computer-using students "displayed more subject/verb agreement" in their writing than other students who did not use the computer, this may well be because the computer-using students "reread and revised their compositions more frequently than a control group using pen and paper." Also bear in mind that, in general, students are inclined to think of technology-based education as "fun" because it is "hands on" and relevant to their world (Thode, 1988).

The computer is a tool in the hands of both the student and the teacher. The effectiveness of that tool depends entirely on the skills that each brings to the learning process. Students are no more passive soakers-up of knowledge than teachers are robotized imparters of knowledge. As educationists from Dewey on have emphasized, children learn best when they are actively engaged in, and in control of, their own education (Harris, 1991). Constructivism also emphasizes the dual role of teacher and student in maintaining a "zone of proximal development" (Vygotsky, 1962) which is defined by Harris (1991) as "the area between what a learner can do independently

¹ "Literacy" is here used in the sense of "possession of education" (Random House, 1991). It should be remembered that in these waning years of the 20th century there are still countries where the universal right to even an elementary education is a novel and barely implemented phenomenon.

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

(mastery level) and what can be accomplished with the assistance of a competent adult or peer (instructional level)."

The outcomes of the computer-based systems for teaching and learning described in the following pages likewise are not automatic; they are the result of a collaboration between the teacher, the student, and the designers of the technology with the goal of preparing an environment for effective learning.

Reading One of the most celebrated computer-based systems for teaching early reading and writing has been that developed by Dr. John Henry Martin in cooperation with IBM. This system, called *Writing To Read*TM, has been in use since 1982 and has been thoroughly evaluated both by the Educational Testing Service (ETS), commissioned by IBM, and by other independent researchers.

We are interested in how effective the *Writing to Read* program has been in improving on more traditional methodologies for helping children of kindergarten and first grade age to learn to read and write. If rapid progress and joy in learning are a measure of a program's effectiveness, then *Writing to Read* has been very successful. The program is in operation in schools across the United States, and one cannot but be impressed by the philosophy and pedagogy that has guided its development. In fact, one is reminded of the methodologies employed in the Montessori schools where children "explode" into writing after learning the letters and the sounds associated with those letters (Standing, 1962). However, Montessori's children do not need computers to discover reading by themselves once they are ready to make the leap from writing the letters associated with the sounds that make up language. So, the question remains: Do the computers in the *Writing To Read* program make any significant difference?

Studies such as Murphy (1984) note that the program has been more effective in teaching writing than reading, putting *Writing to Read* students significantly ahead of non-*Writing to Read* students in terms of writing skills. However, the results also showed that eventually the non-*Writing to Read* students caught up with their *Writing to Read* counterparts. The program gave participants a jump start on basic literacy skills, but neither the advantage gained over non-*Writing To Read* students nor the rate of progress were sustained after the program was completed. Indeed, a year later the *Writing to Read* students' writing skills had declined slightly while the non-*Writing to Read* students continued to improve.

Olson (1987) provides a further caveat. Teachers involved with *Writing to Read* classes tended to have their students spend more time reading and writing than had been the practice in previous years. So any conclusions about the effectiveness of the program as compared with other well-researched alternatives remain tentative.

A major question mark about *Writing To Read* relates to cost-effectiveness. Slavin (1990) indicates that first year costs per lab were high (and more than three times the manufacturer's list price). The reason for the discrepancy is that the list price did not cover all expenses involved with the system. By contrast, research has shown that reading programs sponsored by the U.S. Department of Education (Alphaphonics, MECCA, TALK, MARC, and INSTRUCT) that cost just a few hundred dollars per class, have been at least as effective as *Writing To Read*.

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

Larter (1987) corroborates the conclusions of the research into the *Writing To Read* program when she notes that using computers did not significantly improve students' reading in either the first, third, or sixth grades. Some researchers have found that students of all ages have difficulty reading and writing online. One reason for this may be that computer-based reading and writing requires users to learn to cope with online texts, screens, and file directories instead of the printed page and tables of contents—what Selfe (1992) calls a "multi-layered literacy."

Certainly, good old-fashioned books take some beating when it comes to reading in general. Ergonomically-speaking¹, there is a lot to be said for reading a book curled up in an armchair in front of a warm fire or lying out in the sun on a lawn, a deck, or a beach. Scrolling through the text on a notebook computer does not have the same carefree, relaxed feel to it; it's almost as if the machinery might get in the way of one's enjoyment and interfere with one's concentration. The goal of any learning environment, however, is to foster learning, and the data confirm that the *Writing to Read* program achieves this goal. If money is no object, and the learning is enjoyable, too, then so much the better.

The jury is thus still out on the effectiveness of using computers to help children learn to read. Roblyer (1988), in his review of the research from 1980-1987, found that the use of computer applications for reading resulted in "educationally significant effects," and that "tutorials² seem more effective than other kinds of tools in reading." As for so many aspects of using computers in teaching and learning, success may depend on a shift in paradigms. Products such as the [*Waterford Early Reading Program*](#), that use CD-ROM³ technology to bring a book to life with text, full color illustrations *and sound*, need to be studied further. However, as Sivin-Kachala (1998) found in his large-scale review of research studies from 1990-1997, the capability of giving students rich, individualized reading instruction using CD-ROM storybooks is likely to be beneficial since a teacher cannot, under the circumstances, "have that sort of one-on-one time with every student."

Teachers who use optical disc technology such as CD-ROM are enthusiastic about a technology that "has made reading exciting," as one kindergarten teacher at York Central School in Retsoff, New York, put it. "The children feel empowered, and we're definitely seeing an improvement in reading skills" (Electronic Learning, 1992). Of course, anecdotal evidence is easy to come by and therefore should be taken with a grain of salt. But when positive anecdotal evidence abounds it reinforces the outcome of more rigorous research.

Writing Unlike reading, there is a good deal of research confirming the benefits of student use of computers for writing assignments. The conclusions listed below are consistent whether the research focused on learning disabled students or regular students.

- Students using the computer and word processor for writing assignments generally

¹ Ergonomics—also called Human Factors Engineering—is the study of the interfacing (interaction) between people and machines.

² Software that interactively walks the student through a reading exercise.

³ Compact Disc-Read Only Memory: Optical disc-based medium, now replaced for the most part by Digital Video Disc (DVD), it enables users to more easily work with full-color, interactive graphics and sound along with text. The technology will be discussed further in chapters 2 and 8.

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

felt more positive about the writing instruction they received and about their own writing skills (Kurth, 1987,1, 2; Roblyer, 1988; Klenow, 1991);

improved the quality and fluency of their writing (Burnett, 1984; Muldrow, 1986; Bigley, 1986; Cirello, 1986; Larter, 1987; Klenow, 1991; Lowther, 2003);

were more self-motivated with regard to the subject-matter of their writing (Rosegrant, 1985);

were motivated to achieve literacy because of the computer's visual, auditory, and physical support (Rosegrant, 1985);

improved in literacy because they were encouraged to read what they had written (Rosegrant, 1985; Lowther, 2003);

found software useful for tutoring, writing theory, getting ideas, organizing thoughts, composing, providing feedback, and communicating with others (Frase, 1987; Lowther, 2003);

wanted to write more (Roblyer, 1988; Lowther, 2003).

- With regard to revising their work, students using the computer and word processor for writing assignments

were more self-motivated to revise drafts and spent more time on the process (Pearson, 1986; Souviney, 1986; Hague, 1986; Hawisher, 1986; Muldrow, 1986; Kurth, 1987,1; Katz, 1987; Dalton, 1987; Eastman, 1988, 1989; Klenow, 1991; Lowther, 2003);

produced higher quality revisions than revisions completed using pen and paper (Daiute, 1986; Muldrow, 1986; Kurth, 1987,1; Kurth, 1987,3; Eastman, 1989; Lowther, 2003);

when using the computer's readability measure competed to see who would write at the highest grade level and increased grade level from first draft to revised draft which encouraged them to revise their drafts (Hague, 1986);

adapted more easily to composing on a computer when emphasis was put on revising as opposed to advance planning¹ (Lansing, 1984; Lowther, 2003);

read over and revised their compositions more frequently and more readily than a control group using pen and paper (Rust, 1986; Butler-Nalin, 1987; Kurth, 1987,1; Eastman, 1988, 1989; Lowther, 2003);

made revisions that involved an increase in the length of the composition (Daiute, 1986; Rust, 1986; Bigley, 1986; Cirello, 1986; Kurth, 1987,2; Eastman, 1989).

- With regard to the mechanics of writing, students using the computer and word processor for writing assignments

¹ Students who planned their written work in advance would not need the help of interactive revision as much as those who didn't plan their work ahead of time.

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

more readily developed conceptual abilities since they did not have to physically create the symbols with which they expressed those concepts (Daiute, 1985,2; Rosegrant, 1985; Souviney, 1986);

composed more fluently than they would have with pencils and pens because of the automatic recopying and printout features of computers (Daiute, 1985,2; Rust, 1986; Souviney, 1986; Eastman, 1989; Klenow, 1991; Lowther, 2003);

found that triple-spaced copy made editing easier (Rust, 1986);

felt that keyboarding did not interfere with writing¹ (Muldrow, 1986; Cheever, 1987);

prepared computer drafts that contained fewer words than pen and paper drafts when composing time was limited to 15 minutes, and longer drafts than with pen and paper when more time was allowed (Daiute, 1986);

were more concerned with the aesthetic quality of their text—layout, appearance, and so forth (Daiute, 1985, 2);

preferred the word processor over pen and paper for writing (Burnett, 1984; Larter, 1987; Klenow, 1991);

produced significantly enhanced science-related documents through the use of the word processor (O'Brien, 1986).

- With regard to the reduction of errors in writing, students using the computer and word processor for writing assignments

showed the most dramatic gains in reducing grammar, punctuation and capitalization errors, and in displaying more subject/verb agreement when they initially demonstrated the lowest ability (Muldrow, 1986; Cheever, 1987; Dalton, 1987);

overlooked fewer errors than when using pen and paper (Daiute, 1986; Klenow, 1991);

made fewer grammar, punctuation and capitalization errors (Cheever, 1987; Lowther, 2003);

displayed more subject/verb agreement than those who did not use the computer (Cheever, 1987).

- With regard to effects not directly related to writing, students using the computer and word processor for writing assignments

may more easily have made the difficult transition from speech to writing (Daiute, 1985, 2);

may more easily have developed self-awareness because of the interactive capacities of a computer (Daiute, 1985,2);

may have found the computer to be a catalyst in the development of writing skills as adolescents (Curtiss, 1984; Pearson, 1986; Cirello, 1986);

¹ This conflicts with Selfe's (1992) caveat about "multi-layered literacy" discussed earlier in the chapter.

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

Using prompting programs to help students compose As Daiute (1985,3) observed, in some schools students have been given the opportunity to use the computer and word processor in conjunction with a prompting program such as *Writing Process Workshop* (from Educational Activities), or *Success With Writing* (from Scholastic). These programs are designed to stimulate interaction between the students and their writing.

Students using the computer and word processor in conjunction with a prompting program:

made more interactive revisions than when using only the word processor especially if they were beginning writers of all ages (Daiute, 1985,3; Daiute, 1986);

increased their level of reading and rereading their written work (Daiute, 1985,3).

Caveats re: computer use for writing The following research findings remind us that no methodology, no tool, is suited to all situations, and that sometimes the methodology or tool can create or reveal new, unanticipated problems.

Children of seven years of age or younger may lack the cognitive skills necessary to socialize and collaborate effectively, in writing or otherwise; the writer's age, level of cognitive development, and composing style is critical to how the computer tool is used (Daiute, 1985; Daiute, 1985,2);

Students working collaboratively will not find collaboration effective for all writing tasks, and should work independently on some writing tasks in order to assure maturation of the writing process (Daiute, 1985);

The computer is less useful if the hardware or software design is complicated; all computers should ideally be of the same brand and model so as to facilitate group instruction and interaction (Daiute, 1985,2; Frase, 1987; Eastman, 1988);

Computer writing needs to be integrated with the use of other traditional writing and drawing tools (Daiute, 1985,2);

Some students found using the keyboard and working with text on line inhibited their writing ability (Curtiss, 1984; Dalton, 1987; Eastman, 1988, 1989; Selfe, 1992);

Some students neglected planning when using the word processor (Dalton, 1987)¹;

There needs to be an adequate number of computers for students to work simultaneously and individually (Eastman, 1988; Lowther, 2003);

Pedagogical styles will need to change to accommodate the use of computers (Daiute, 1985,2; Eastman, 1988, 1989; Tierney, 1992; Lowther, 2003);

Sixth grade students using the word processor did not necessarily produce better quality writing than those using pencil and paper (Larter, 1987);

¹ Perhaps because revisions were so much easier to make—which is a problem, since planning is always important.

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

A few researchers found the computer made practically no difference as regard many aspects of the writing process (Lansing, 1984; Strickland, 1987; Kurth, 1987,1; Roblyer, 1988);

Viewing written work on a computer screen does not appear to help the writing process—hard copy may be the preferred medium for review of written work (Lansing, 1984).

Arithmetic and problem-solving Let us now review the research conclusions regarding the effectiveness of computer use in teaching and learning math and problem-solving.

eighth grade students who used simulation and higher order thinking software showed gains in math scores of up to 15 weeks above grade level as measured by the National Assessment of Educational Progress (NAEP) (Wenglinksky, 1998);

eighth grade students whose teachers received professional development on computers showed gains of in math scores of up to 13 weeks above grade level as measured by NAEP (Wenglinksky, 1998);

showed math achievement gains that were significantly greater than the control groups who did not use the computer (Foley, 1984; Roblyer, 1988; Fletcher, 1990, Wenglinksky, 1998);

spent 50% of all computer time learning programming skills (problem-solving) at the high school level (Becker, 1987);

were more likely to be helped in basic math and language skills if they were lower-ability students; higher ability students benefited in terms of higher cognitive skills such as problem-solving and programming (Ayoubi, 1985; Samson, 1986; Becker, 1987; Thode, 1988);

improved problem-solving skills when using Logo as a platform for programming (Spence, 1987, Roblyer, 1988);

learned concepts such as fractions and binary operations of fractions, graphing, and algebraic precedence conventions significantly more effectively when provided with computer-based experiences in addition to teacher-directed activities as opposed to students who received only teacher-directed activities (Marty, 1985; Al-Ghamdi, 1987; Ball, 1988, Wenglinksy, 1998);

scored significantly higher on measures of their ability to transfer skills learned with the aid of the computer to other areas of mathematics (Al-Ghamdi, 1987; OTA, 1988).

Caveats re: computer use for learning math and problem-solving Joseph Weizenbaum, professor at the Massachusetts Institute of Technology, points out that there is "no more evidence that [problem-solving in the form of computer programming] is good for the mind than Latin is, as sometimes claimed" (Spence, 1987). Other researchers found that students using computers for math and problem-solving

were not affected as to their attitudes towards math or computers (Foley, 1984, Marty, 1985);

were not affected with regard to class attendance (Foley, 1984);

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

were as likely to find math and computer programming equally difficult (OTA, 1988);

Harold Wenglinsky's 1998 national study of technology's impact on mathematics achievement further found that eighth-grade students who used technology to play learning games and develop higher order thinking performed only 3 to 5 weeks ahead of students who did not use technology (Wenglinsky, 1998). He also found that fourth- and eighth-grade students who use drill and practice software performed *worse* on NAEP than students who did not use drill and practice technology (Wenglinsky, 1998).

Science In the science classroom, students interacting with computers running simulations of experiments enjoyed a more effective learning experience than students watching a demonstration accompanied by teacher-student interaction. Simulated or real experimentation seems to provide the benefit of *involvement*—a characteristic of quality learning so ardently advocated by Thomas Edison. "The most important method of education," Edison once remarked, "always has consisted of that in which the pupils were urged to actual performance."

Here is some of the feedback from research into computer-integrated science education. Students who used the computer in the science classroom:

achieved more from computer-based laboratory activities and/or computer simulations than students who studied in a conventional learning environment (White, 1984; Shaw, 1985; Roblyer, 1988);

were more likely to benefit than when using computers for learning in other content areas (Roblyer, 1988);

more effectively learned to generate graphs, to identify trends in graphs and to understand the meaning of information presented in graphs developed during experiments than students developing graphs by hand (Linn, 1987);

were more easily able to transfer understanding from one type of physical activity to another when generating graphs during experiments in microcomputer-based laboratories (Linn, 1987; OTA, 1988);

were able to use the computer as an oscilloscope, temperature probe, pressure sensor, light sensor, etc. by connecting sensors and probes to it, thus extending the use of the computer as a laboratory instrument for science studies at a fraction of the cost of the actual instruments (McCarthy, 1992);

gained skills likely to be valuable throughout their lives when learning how to collect, analyze, and interpret data (Rash, 1990);

produced science-related documents that were significantly enhanced through the use of word processing (O'Brien, 1986).

Caveat re: computer use for teaching and learning science Not all researchers came to the same conclusions. Ayoubi (1985) and Choi (1987) found that students who were given the opportunity for computer-based learning of science gained no advantage in computer-simulated experiments over students who conducted the same experiments hands-on, when the students

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

were of average ability. It was also noted that students were involved mostly in drill and practice when using software related to the physical sciences (Hegelson, 1988).

Social studies The following are some outcomes of research into the effectiveness of computer use for social studies.

Social studies benefit from the increasingly varied access to computerized databases of appropriate information (Hunter, 1987). Data Base Management Systems (DBMS) simplify access to large volumes of data covering most subjects in the social studies curriculum. The databases are both local and remote, the latter being accessed via communications media such as the telephone system.

Cohen (1987) drew conclusions similar to those of Hunter. Students were given access to electronic information via online databases. As expected, access to information was quicker, and students developed research skills as well as skills related to computer use and telecommunications.

Studies across the curriculum benefit from using the computer to create, store, retrieve and randomly display data. Students are more easily motivated when using the computer for these activities (Ferguson, 1989).

Massialas (1987) found teachers K-8 enthusiastic about the use of computers for social studies, even though the integration of computers into the curriculum proved complex. The introduction of computers may result in the beginning of curriculum change. It is interesting that Massialas also found that computer use led to an increase in social skills.

Teachers from Fourth through Twelfth grade found that interactive videodiscs provided a multimedia environment that simplified the sequencing and presentation of relevant, high-quality visual information as a supplement to traditional social studies lessons (White, 1990). White noted that videodisc technology was most effective when used in conjunction with a microcomputer running software such as *HyperCard*.

Audio-telecommunications systems such as voice mail promote the bridging of oceans and cultures, increasing students' global awareness and international understanding (Galvin, 1989). Voice mail cuts across time zones because it allows students to take up a conversation at any time they choose. Conversations can also be duplicated and shared with other users. Diem (1989) reports on video-conferencing technology used to teach students the nature and importance of global interdependence. Chapter 7 will expand on these technologies when discussing the effectiveness of computers and communications (C&C) in the learning process.

The computer is a useful tool (word processing, database management, simulations, tutorials) for learning traditional social studies concepts (Lengel, 1987; OTA, 1988). Budin (1987) identified the following as directions to pursue in the use of computers in teaching social studies.

1. Develop more software that involves students in decision-making in regard to social studies issues, and expects more input from them;
2. Use software that makes more use of graphics to convey subject-matter;

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

3. Use technology such as telecommunications to increase students' global understanding;
4. Use the computer to stimulate more social interaction on the part of the students.

Students are learning to be more effective in finding meaning in data because of the ease with which large amounts of data can be displayed graphically using microcomputers (Hinze, 1989).

Caveats re: computer use in social studies Teachers were concerned about the lack of software. They found a lack of correlation between some of the available software and instructional goals. Teachers also considered themselves inadequately prepared to use computers in the social studies classroom (Massialas, 1987).

According to White (1987), incorporation of the computer into social studies education was most effective when teachers were well trained and were prepared to spend extended time to make the computer-based programs work. Success was also associated with cooperation from institutions outside the school who served as partners.

Schug (1988) found that far more teachers had received training than were presently using computers even though most teachers expected to be using them more. This suggests that either the training was inadequate, or that access to computers was too restrictive to warrant incorporating them into the curriculum, or that the available social studies applications were considered unsatisfactory.

Computer-assisted collaborative learning Teachers in all subject areas are discovering that computer-based learning lends itself to collaboration between groups of students. This is especially true when students are encouraged to work together on writing and other language arts assignments. Such students

surpass students in control classrooms on measures of depth of understanding, reflection, and also on standardized reading, language, and vocabulary tests (Scardamalia and Bereiter, 1996; Lowther, 2003);

worked best in small groups of two, three or four students (Daiute, 1985,1; Ayoubi, 1985);
were more often girls than boys, suggesting that collaborative work is more successful with girls (Johnson, 1985);

shared more ideas with classmates than those using traditional methods of composition (Daiute, 1985,1; Heap, 1986; Kurth, 1987,1; Klenow, 1991; Lowther, 2003);

appeared to help each other learn appropriate writing techniques (Daiute, 1985,1; Daiute, 1985,2; Eastman, 1988, 1989; Klenow, 1991);

were encouraged to collaborate because it was simpler to add to and arrange common text (Heap, 1986; Muldrow, 1986; Lowther, 2003);

produced a higher level of achievement in terms of mastery and application of factual information as compared with individualistic learning (Johnson, 1985);

had very little interaction with the teacher (Johnson, 1985).

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

One-to-one computing Fully effective integration of computer-based technology in the classroom will only happen when every student has access to a personal computer all the time (Zucker, 2005, Penuel, 2005, 2006, and Brumfield, 2006).

This is referred to as *one-to-one computing*.

A growing number of schools, in some cases sponsored at the state level, are purchasing laptop computers for all the students and all the teachers. The idea is that the computer should be as ubiquitous in schools as the textbook—along with the chalkboard, and pen and paper, of course.

For example, the state of Indiana has the ACCESS (Affordable Classroom Computers for Every Secondary Student) program which negotiates discounted computer purchases with computer suppliers and sets them up with the *Linux* operating system and *Open Source* software.

Both *Linux* and *Open Source* software are free.

“Each computer,” the Indiana Department of Education report (2005) says, “is equipped with a complete *MS OFFICE* compatible office suite (Star Office 8), networking software, Mozilla's *Firefox* browser, email if desired (*Evolution*), photo editing software (*GIMP*), CMAP – Concept Mapping Software, VNC, and Codeweaver's *Crossover Office* (WINE).”

“Future installs,” the report states, “will include *ITALC* software to allow teachers to monitor student workstations, and also *Scribus*, an open source illustration and layout program. Thousands of other open source programs are available for other purposes.”

The Indiana ACCESS program is a work in progress with long-range one-to-one computing goals.

It seems inevitable that, in time, one-to-one computing in K-12 schools will be ubiquitous and as inexpensive as today's cell phone. We are still a long way from universal availability of one-to-one computing in schools. It is, however, a goal "devoutly to be wished," as Shakespeare would say.

The potential benefits of one-to-one computing are hard to dispute. Zucker (2005) reports that "Policymakers' goals for laptop programs include increasing economic competitiveness, reducing the inequity in access to computers and information between students from wealthy and poor families, raising student achievement through specific interventions (such as improving students' understanding of algebra through the use of education software), and transforming the quality of instruction.”

The world at large is seeking to embrace one-to-one computing. Nicholas Negroponte's [One Laptop Per Child \(OLPC\)](#) program, established in 2005, is seminal and serious in its goals. China, Nigeria, and Thailand are already working with the OPLC initiative to provide computers for every single child in their neck of the woods. What a fabulously ambitious—and realizable—goal!

The future in K-12 schools is one-to-one. We are in a period of rapid transformation from one instructional paradigm to another. We teachers **MUST** be ready for tomorrow's world in schools.

But let us never forget that a successful K-12 one-to-one computer program requires careful planning, strong leadership at all levels, adequate funding, carefully implemented logistical and technical support, and, above all, ongoing training for teachers, students, and parents.

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

WHY IS IT TAKING SO LONG FOR SCHOOLS TO CHANGE?

Marcinkiewicz (1994) noted that only about half the teachers in his study were using computers at all for instruction. The U.S. Department of Education National Center for Education Statistics (1999) noted that "relatively few teachers (20%) report feeling well-prepared to integrate technology into classroom instruction." A 2006 survey (Broomfield, 2006) conducted by CDW-G, a reseller of hardware tools to schools and governments, and administered by education research firm Quality Education Data (QED), suggests that the situation has somewhat improved; "81 percent of those surveyed said they used technology for research purposes when preparing lessons, and 79 percent use technology as a teaching tool in the classroom." Moreover, according to the survey, "four out of five teachers indicated that technology is very or somewhat important to teaching. Eighty-eight percent of those surveyed said technology is important to administrative functions such as attendance and grading, while 86 percent agreed it was important to communications with other teachers, administrators, parents, and students."

Yet 55 percent of those surveyed "believe the biggest impediment to effective technology integration is access to computers; 48 percent believe they lack sufficient time to properly integrate technology into lessons; and another 48 percent say district budgets do not allow the level of technology integration they would like to see in their classrooms."

If computers are such a boon to education, why is it that so few teachers have developed curricula that incorporate their use? Here are some perhaps obvious reasons.

Until the waning years of the 20th century, desktop computers were unable to run sophisticated learning programs because they were not powerful enough Early software was very limited in what it could do. If the program used graphics it ran too slowly, and the images were primitive by contemporary standards. If it lacked graphics, animation, or audio-visual interactivity its interest value was diminished significantly.

Still today, with the new millennium upon us, computer technology along with the computing infrastructure to support it is too expensive to justify the purchase of computers in sufficient numbers to make a significant impact in a school Too few teachers have up-to-date networked computers on their desks. This means that most teachers, whether they like it or not, have to do without them most, if not all, of the time while they are working with students. The same is true of students. In 1988, Bulkeley had already noted that schools that purchase computers are faced with the expense of replacing old machines before they can even think about adding more computers. And in any case, Herb Lin of the National Academy of Sciences observed that "even if there were one computer per classroom, that's less than two minutes per student for a one-hour class" (Borrell, 1992). There is a need for infusion of computer-based learning technology to the point of saturation in the classroom and the home. Computing in the home is reaching this point in economically-advanced nations such as the United States where the online computer is rapidly becoming as ubiquitous as the TV. But in the classroom, even in the United States, many students are provided with few, if any, computers and too often those computers are old.

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

Educators are no different than other people; they resist the change made possible by interactive computing Marcinkiewicz (1994) cites Nickerson (1980) who gave five reasons why people who might benefit from interactive computing systems nonetheless balk at using them. First, there is a natural resistance to change. Second, they fear that automation will lead to loss of status. Third, many potential users, teachers included, are ignorant of the potential of computers. Fourth, there is a fear of replacing familiar procedures with unfamiliar ones. And fifth, people like to do things the way they've learned to do them and fear the loss of hard-earned skills.

Flexibility should be designed into school schedules Elmer-Dewitt (1991) points out that at most age levels in most schools, the time frame around which lessons are planned is about 40 minutes. But when students work together on a project that uses the computer for research, data analysis and presentation, this time frame is too short. To some extent, computer technology will begin to be used most effectively when schools allow for a schedule in which the day is divided up along more flexible lines, with a *mix* of time frames depending on the topic and medium of instruction (Riel, 1994).

There are other reasons for the slow pace of change Bulkeley (1988), Cuban (1986, 1997), Milken Exchange/ISTE (1999), and Brumfield (2006) add the following explanations for the uneven and limited penetration of technology into teaching practice:

- Teachers have inadequate opportunities for training and poor access to technology. Strategies for implementation are thus often flawed. In 1988, 32% of the computer-education coordinators in elementary schools admitted they were uncomfortable with computers, according to an Educational Testing Service survey (Bulkeley, 1988). By 1999, as already noted, only 20% of teachers felt prepared to integrate technology into the classroom (U.S. Department of Education, 1999). While most school districts now boast computer-education coordinators who are comfortable with computers, those coordinators' hands are typically tied by an appalling lack of resources, especially resources to provide support for ongoing training for the teachers.
- A surprisingly large number of colleges of education still do an inadequate job of preparing student teachers for a technology-based teaching paradigm.
- Integrating computers into instruction is much more difficult than expected and demands considerable preparation even for well-trained teachers.
- Classroom demands of various kinds—class size, heavy teaching schedule, other teacher responsibilities unrelated to teaching, and so forth—take away from a teacher's commitment to computer-based teaching and learning. As one teacher put it: "I've been too busy teaching to integrate the computers" (Bulkeley, 1988).

A useful exercise would be to come up with your own reasons for the slow pace at which computer-based technology has been incorporated into instruction. These reasons might reflect your own experiences in the classroom, as either a student or teacher.

That the transition to computer-integrated curricula is slow should not surprise us; nor should it deter us from continuing to move forward. The April, 1992 report of the Council of Chief State School Officers, as relevant today as it was in 1992, called for access to technology "for all

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Chapter 1: Technology Use in Teaching and Learning: What's the Return on Investment?

students" along with a proposal for "a series of sweeping measures to integrate technology on a broad scale in schools." Since effective leadership is so crucial to success, we must hope that commitments such as this, necessary but yet not sufficient for successful technology implementation in schools, will be taken up by administrations at all levels of government.

COMPUTER-INTEGRATED TEACHING AND LEARNING: THE TEN PILLARS OF SUCCESS

Here are some prerequisites for successful implementation of a technology program as a basis for further discussion (Table. 1.1).

<p>The Ten Pillars of Successful Technology Implementation</p> <ol style="list-style-type: none">1. Leadership must provide active and committed support2. Selling is better than telling—everyone needs to buy in to the change that technology brings3. Invest in, and train, a core of teacher-technologists4. Recognize that technological change is fast—keeping up-to-date is challenging and essential5. All teachers must receive on-going training6. All teachers must receive technical support—ideally on-site and on demand7. Use it or lose it—teachers must plan on integrating technologies in order to maintain currency and fluency in its application8. Parents and students must be actively involved in the evolutionary process9. There must be planned and systematic financial investment in technology-integrated teaching and learning10. Recognize that technology is for all, and that it involves all in the process of lifelong learning

Table 1.1 The Ten Pillars of Success

In chapter 13 we will return to these Ten Pillars of Successful Technology Implementation in Schools and discuss them in greater detail. For now, read them, think about them, and discuss them with your classmates or colleagues. Every single one of the pillars needs to be in place for the successful implementation of technology for teaching and learning in our schools.

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LOOKING BACK

This chapter has presented feedback from the collective experience of many educators and educational researchers with regard to the effective use of computer-based tools in schools. More work needs to be done. Current conclusions remain tentative though predominantly positive, suggesting that experimentation should continue with a view to helping teachers make wise decisions about ways and means of incorporating the computer into the curriculum. Experience also bears out the obvious caveat that any application of computer-based technology should be carefully evaluated as to its effectiveness. We'll return to this theme in chapters 4 through 9 when we examine the technologies and methodologies involved in computer-based learning and teaching.

Lewis Perelman, Director of Project Learning 2001 at the Hudson Institute, fires something of a broadside at people who continue to question the potential contribution of computer-based technology in schools. "Two decades of research," Perelman (1990) writes, "show that computer-based instruction produces at least 30% more learning in 40% less time at 30% less cost compared to traditional classroom teaching."

The leviathan that is education is stirring. When people look back on this period in the history of education, they will conclude that the invention of the computer was a critical catalyst for fundamental change in the way people learn, just as it is proving to be a catalyst for change in the way people live. Today we are on the threshold of this change, which means that these are difficult times. No one likes to let go of successful but outmoded methodologies. Teachers in training do not have much experience on which to base innovation since, for the most part, they were taught in traditional ways. But the pioneers are out there in the schools, and some of them are profiled in the Case Studies that accompany each chapter. Others are profiled in the many publications related to teaching in general, and to teaching with technology in particular. Appendix B reviews a selection of this recommended reading.

LOOKING FORWARD

Ideas are one thing, innovation another. Computer-integrated curricula yield significant benefits for students. This is recognized time and again in the hundreds of articles on this theme published every month in magazines and journals devoted to educational issues. Attend any of the dozens of conferences on educational computing that take place every year around the world and you will meet, unfortunately still very much in the minority, teachers who are taking the technology into their classrooms and, as we shall see in chapters 4 through 9, making it work for them and for their students.

But innovation requires hard work, planning and discipline. It does not just happen. Multitudes of teachers have attended seminars, workshops, conferences, even semester-long courses, where they have had the opportunity to learn how to use computer technology as a tool for teaching. A large proportion of these teachers have come away with a new-found enthusiasm for the methodologies involved. Too often, however, they have returned to their schools only to have that enthusiasm and excitement wane as reality brought home to them the extent to which they would have to change the way they have routinely run their classrooms.

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The translation of ideas, and enthusiasm about those ideas, into practical implementation is often difficult. We should therefore not be surprised if change is slow in schools. Peters (1984) references the work of Theodore Levitt (1981) on the subject of ideas (creativity) and innovation in the business world. Levitt describes how difficult it is to effect change through innovation and makes a distinction between creativity and innovation. "Creativity," he says, "is thinking up new things. Innovation is *doing* new things..." Many people come up with good ideas that will improve the way things are done in schools; too few people are prepared to *do* what is necessary to implement their ideas.

Ideas take on life when they are realized through action. As Levitt points out: "Ideas are useless unless used." So we should resolve to be innovative as well as creative. Better yet, we should resolve to help others be innovative by our example, by our encouragement, and by our willingness to give our time and energy to promote the integration of technology across the curriculum at all levels of teaching and learning in our schools.