

# **Learning Technology:**

## **The Effective Use of Technology in Education**

**A report on the  
status of technology  
in preparing students  
for the workplace**

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**Center for Occupational Research and Development**



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# **Learning Technology: The Effective Use of Technology in Education**

## **Executive Summary**

### **Overview of the Problem**

In the past few decades, technology has transformed our world—improving and expanding our opportunities for communication, education, and employment. Because the effects of the Information Age have transformed the needs of business and industry, modern employers now seek a new breed of worker—a worker who not only can perform designated tasks, but who also can operate and apply new technologies. Unfortunately, studies indicate that the majority of our nation’s students are not receiving the preparation they need to successfully compete in the modern job market. Although many schools are equipped with computers and other technologies, a surprising number of teachers struggle to effectively integrate technology into curricula. In the meantime, students lose valuable time in their preparation for the world, and workplace, they will soon enter.

Teachers, who often find themselves scapegoats for the nation’s educational shortcomings, are not to blame for this predicament. Most educators realize the importance of technology in the classroom and worry about their inability to incorporate it into curricula. These teachers have indicated many reasons for the difficulty of integrating technology: reasons that command attention from administrators and policymakers. In many cases, schools purchase complex equipment for classroom use without providing teachers the professional development time needed to learn equipment operations and applications. In other situations, educators are concerned that integrating technology will upset established, accepted curricula. Still others fear technology will minimize the role of the teacher in the classroom and will deprive teachers of student contact and the sense of accomplishment that can result from a career in education.

If our country is to successfully integrate technology into education, we must address the needs and concerns of those on the front lines—our nation’s teachers. This effort requires increased open communication among all of education’s key players. Administrators and educators must collaborate with other educators, and consult available research, to determine technologies suitable for each classroom. These efforts will aid teachers in integrating technology into curricula, which will bring a wider range of resources into the classroom; motivate learners; provide teachers with effective new tools; accommodate individual student learning needs; and positively enhance, rather than minimize, the role of the teacher—from transmitter of knowledge to facilitator in the learning process.

## Review of the Research

In the past couple of decades, researchers have extensively studied the effects of technology in the classroom. Research findings on effective applications remain inconclusive, however, because technology is expected to play a variety of roles in education. Before researchers find solid evidence of the effectiveness of educational technology, they must agree upon the purpose it best serves. While technology can dramatically enhance teaching and learning, it cannot fill needs for which it was not designed; it cannot, in and of itself, transform teaching or learning. Rather, educational technology should serve as a tool to facilitate higher-order thinking skills, problem-solving capabilities, and an interest in learning among students. Educators who have experienced success with technology suggest that effective integration of technology requires users to exercise creativity and reasoning in conjunction with academic skills.

Rather than requiring of students higher-order thinking and problem-solving skills, education's most widely used technical application involves students in rudimentary "skill drills." For a number of reasons, studies indicate that *computer-assisted instruction (CAI)* is not preferable to teacher-led whole-group instruction, does not allow students to exercise creativity and problem-solving skills, and fails to address the learning needs of all students. A number of technological innovations, however, show promise as more effective means to supplement the twenty-first-century classroom. These innovations include *distance learning*, which involves the transmission of quality communications and experiences to students at a variety of locations, in close proximity to one another or around the world. Of the configurations of technology through which distance learning can occur, *two-way audio and two-way video telecommunication* allows both students and instructors to hear and see one another and to participate in demonstrations, experiments, and virtual workplace experiences.

Another effective method of integrating technology, *concept and applications programs* represent the culmination of technology as a learning tool, encouraging students to rely not only upon stored knowledge, but also on uniquely human reasoning and problem-solving skills. These programs require students to exercise academic skills and knowledge, technical literacy, and higher-order thinking by participating in challenging, stimulating simulations and games. Concept and applications programs enable users to exercise higher-order mental operations by relieving them of a majority of lower-level calculation and memorization tasks. Students working with concept and applications programs not only learn how to use computers, but discover ways technology can assist them in life and on the job.

Finally, the presence of the Internet in classrooms can bring a new world of educational experiences to students everywhere. Teachers who have access to telecommunication resources remark that Internet use enables their students not only to learn about

technology, but to communicate with students in other social settings and broaden their world views. In addition, some telecommunication networking projects encourage cooperative learning experiences among students. Since telecommunication networking is fairly new in the educational arena, parents and educators worry that students may access inappropriate materials through its use. Ironically, the capabilities that concern some adults are the same capabilities that thrill others as they see the potential of telecommunication to show students the world beyond the classroom. Issues of student protection and censorship can be ultimately resolved only through more years of trial and error and cannot outweigh the valuable experiences this technology provides.

### **Implications of the Research**

In the review of findings for this report, researchers at the Center for Occupational Research and Development (CORD) determined several issues highly relevant to the effectiveness and potential use of technology in education—issues that have yet to be addressed sufficiently to form conclusive recommendations for educators. The manner in which these inquiries are addressed will directly affect the degree to which new technology enhances teaching and learning opportunities.

#### **Question one:**

What specific elements of computer software programs most effectively enhance the learning experience?

#### **Question two:**

Is it possible to develop effective software that incorporates the proven pedagogies of cooperative learning, higher-order thinking, integrated learning, and multiple intelligences, while using real-world applications of mathematics and science concepts?

#### **Question three:**

If software incorporating the proven pedagogies of cooperative learning, higher-order thinking, integrated learning, and multiple intelligences, and using real-world applications of mathematics and science concepts, can be developed, will it prove effective in actual classroom settings?

#### **Question four:**

Is it possible to deliver, via two-way audio and two-way video telecommunication, meaningful, real-world worksite learning experiences?

#### **Question five:**

If effective worksite learning experiences can be delivered via two-way audio and two-way video telecommunication, to what degree can they improve student understanding of

the world of work and its relationship to the mathematics and science concepts learned in the classroom?

**Question six:**

If distance education via two-way audio and two-way video telecommunication is an effective method for teaching and learning, how can professional development opportunities, including on-time coaching, experiments, demonstrations, and discussion groups, be effectively provided to educators, business, and industry?

**Question seven:**

What are the most effective uses of the Internet for enhancement of mathematics and science instruction?

**Question eight:**

How can teachers be prepared to use the Internet and other telecommunication networking to enhance mathematics and science instruction?

CORD is currently attempting to address four of these issues with efforts designed to assist educators in effectively integrating technology. These initiatives are described in “Response to the Research: An Integration of Technology into CORD Curricula.” The other four issues, although equally fundamental to the future potential of educational technology, remain unaddressed by CORD or other organizations.

**Response to the Research: The Integration of Technology into Curricula**

As a not-for-profit organization dedicated to preparing all students for the future workforce, CORD acknowledges and respects the current findings on technology in education. CORD believes that technology, when properly integrated into the classroom, can provide enhanced learning opportunities and brighter futures to all students. In consideration of the current research on technology-enhanced education, and to assist schools in integrating technology into CORD’s applied academics curricula, the organization has initiated four ongoing developments: a review of on-the-market software, creation of CD-ROM computer software, implementation of a network of two-way audio and two-way video telecommunication to foster work-based learning, and the creation of a virtual center to enhance teaching.

The first of these developments involves CORD’s continual assessment of mathematics, science, and career software aimed at the secondary and postsecondary markets to create a framework for educators to use in evaluating and selecting software. CORD’s second initiative, the development of hands-on CD-ROM software adventures, will enable students to practice and apply concepts learned through secondary mathematics. The third initiative, the implementation of a network for work-based learning, will join schools and

key business and industry sites through the use of telecommunication and multimedia technologies, providing work-based learning experiences for students in both urban and rural schools. Finally, CORD has developed and will expand the Virtual Teaching Center, a laboratory studio equipped with the latest in high-technology teaching aids, that will provide real-time two-way audio and two-way video communication and asynchronous professional development experiences to sites throughout the United States and around the world.

Through ongoing research, CORD has concluded that technology has the potential to enhance systemic educational reform in the coming years, reform that prepares all students for the world, and the workplace, in the Information Age. This report seeks to support developments that will help teachers to integrate technology in ways that serve students best by encouraging them to exercise higher-order thinking, creativity, and problem-solving skills. It is CORD's belief that these solutions will strongly aid schools as they attempt to prepare students for the challenges of life ahead.



# Learning Technology: The Effective Use of Technology in Education

## Introduction

Technology has affected all aspects of global life, transforming the way the world works, plays, and communicates. Thus, in this “Information Age,” schools must effectively educate students in the use and application of computers and other forms of technology. As witnesses to this era, we have become accustomed to the benefits of technology, obtaining quantities of information in mere seconds that our ancestors would have worked years to obtain. Nicholas Negroponte remarks in *Being Digital*, “Computing is not about computers anymore. It is about living.”<sup>1</sup> Humanity’s applications of technology can be credited with the establishment of a global marketplace, the introduction of strangers around the world, and notable medical breakthroughs.

Technology in its material forms, however, is not all that remarkable. Without command from humans, computers are little more than glass, metal, and plastic structures. As the catalyst for all technological operations, society bears the responsibility for using computers and other technologies effectively, efficiently, and wisely—a responsibility that will grow with future innovations. Therefore, today’s youth must develop literacy in the language of technology and the language of their respective cultures to function in the world outside the classroom.

As little as twenty years ago, schools were able to provide students with the skills they needed to live and work in the then-modern world. Henry Kepner, an education professor at the University of Wisconsin, asserts that this is no longer true in the Information Age. While American schools have prioritized the purchase of technical equipment, installing an estimated 5.8 million computers (about one computer for every nine students) by the spring of 1995,<sup>2</sup> “The computer-learning revolution . . . just hasn’t happened.”<sup>3</sup>

Educators are realizing that the mere presence of computers in the classroom makes little impact on the technical competence of the nation’s students. According to Joseph Arangio, headmaster of Mario Umana High School of Science in Boston, “The mistake [we made] was thinking that if we put in a lab or two, computer education would happen by magic.”<sup>4</sup> Teachers, who find themselves scapegoats for much that ails education, are not to blame for this predicament—an overwhelming number of them have not been adequately educated in the use of technology or its applications. According to the Office of Technology Assessment of the United States Congress (OTA), a substantial number of teachers with access to computers purposely avoid integrating technology into their instruction because of their lack of training.<sup>5</sup> William Bulkeley comments:

Few teachers publicly criticize computers for fear of appearing technologically backward, but many ignore the machines after one or two frustrating experiences. “It takes a tremendous amount of time to become familiar” with the computers; says a high-school language teacher in Newton, Massachusetts: “I’ve been too busy teaching to integrate the computers.”<sup>6</sup>

Even educators who are familiar with technology are often at a loss to integrate it into classroom instruction. Thus, they teach their students only the most basic of computer operations, failing to demonstrate the relevance of technology to the world and the workplace. To many young people, “technology” means video games and electronic “chat rooms.” Marc Tucker, president of the National Center on Education, comments: “A lot of kids in this country now distinguish between a computer and a telephone . . . I think we should expect a great deal more.”<sup>7</sup> Recent studies indicate that most students having access to computers still possess only basic knowledge of their operation and applications. Educational Testing Service reports that 95 percent of these students can identify pictures of a floppy disk and a keyboard, but they can only guess the answers to questions about computer operation and functions.<sup>8</sup>

Without the help of educators, students will continue to view computers as costly entertainment. Technology cannot earn respect or get attention on its own, nor can it replace teachers in the classroom. Just as a teacher cannot calculate numbers in a fraction of a second, the computer cannot fill the vital role of the teacher in preparing students for the challenges they face as living, breathing adults. In the future, “good” educations will be successful partnerships of teachers and technology, with educators teaching students in the way they learn best to obtain the information technology places at their fingertips. Students simply cannot learn about the many applications of technology through traditional teaching methods where teachers lecture and students absorb knowledge as passive “sponges.” Maushary and Spirt remark: “If the children we teach are to become productive adults, we must give them the best opportunity to gain the knowledge which will allow them to make responsible choices and judgments; we must give them a depth to their studies beyond the memorization of facts and isolated skills.”<sup>9</sup> Tomorrow’s educators must challenge students in learning to think, interact, and solve problems—to learn how to learn with the aid of technology. In turn, students will realize the importance of lifelong learning and become motivated participants in the world, and the workplace, of the future.

The purpose of this report is to examine the current status of technology in education, with an emphasis on two technologies especially relevant to modern classrooms—computers and telecommunication. Through a review of current research, this paper will summarize technology’s current effectiveness in classrooms; the relationship of teachers to technology; the ineffectiveness of computer-assisted drill-and-practice software;

evidence favoring distance learning and two-way, interactive technology; the benefits of concept and applications programs; and the benefits of the Internet in classrooms. This paper will then consider implications of the current findings on technology use in education—implications to be addressed by further research and development. Finally, the report will include the response of the Center for Occupational Research and Development (CORD) to these implications.

### **The Effective Use of Technology in the Classroom**

In the past couple of decades, researchers have gathered a substantial amount of data on the successes and failures of technology in schools. Unfortunately, their differing expectations of the role technology should play in education inevitably affect their findings. *The Technology Age Classroom*, a historical overview of research and trends in the educational use of technology, acknowledges this dilemma:

You would think that after 20-plus years of using technology in schools, there would be overwhelming evidence of its worth as a learning tool. If you think that, you're wrong—there is no overwhelming evidence of the value of technology. There is some evidence; there are research results; there are anecdotal remarks by myriad teachers; there are hundreds of articles about thousands of studies; there are stories of improved attitude, improved attendance, and “saving” of large numbers of students at risk. But for every positive item you read, you can find a contrarian who has found the opposite effect. . . . Much of the ambivalence of research results has to do with the different expectations of what role technology can play in the classroom.<sup>10</sup>

Technology has been expected to wear many hats in the classroom; therefore, it is not surprising that researchers call its value into question. In educational settings, the computer is expected to serve as not only an informational tool, but at different times a teacher, evaluator, and baby-sitter. While it can fill all of these roles in some capacity, technology was never intended as an educational panacea. Technology is not an educational end in itself, but rather a means to an end that must be applied in an effective and appropriate manner. Anne Thompson, in her review of research on educational technology, finds “It is becoming increasingly clear that technology, in and of itself, does not directly change teaching or learning.”<sup>11</sup>

In its 1995 study on teachers and technology, the OTA found that “additional research is needed to develop a deeper understanding of which instructional uses of technology are most effective. . . .”<sup>12</sup> The most effective applications appear to occur where design and implementation features combine with technology to help students achieve both measurable and creative goals. Five common benefits are associated with these

incorporations—benefits that OTA claims “are the most typically mentioned when technology-using teachers use words like ‘transform,’ ‘relevant,’ ‘flexible,’ and ‘motivating’ in discussing why they use technology in their classrooms.”<sup>13</sup> OTA finds that successful applications of technology bring a wider range of resources into the classroom; motivate learners; provide new teaching tools; accommodate individual learning styles; and even redefine the role of teachers.

### **Benefit One: Bringing New Resources into the Classroom**

Since technology has become more readily available to schools, students have access to an environment that offers a wider range of learning modalities. The emergence of telecommunication brings a world of new possibilities to the classroom and dissolves the physical barriers to experiential learning. In addition, appropriate use of technology can engage students in fully exercising their potentials or “intelligences.” In his book, *Multiple Intelligences*, learning theorist Howard Gardner argued that individuals may possess as many as seven forms of intelligence: linguistic, logical/mathematical, musical, spatial, kinesthetic, interpersonal, and intrapersonal.<sup>14</sup> The use of some technologies, especially those involving multimedia, requires students to combine and exercise their multiple, varying intelligences, talents, and abilities. Finally, educational technology can aid students in developing interpersonal skills by enhancing their interactions and encouraging teamwork.

### **Benefit Two: Motivating Learners**

Learning through technology is far more exciting than traditional lecture and practice modes. Educational technology reaches students through a variety of senses, keeping them alert and interested in classroom activities. In addition, students actively involved in learning with technology assume responsibility for their education, developing the skills to continue learning years after formal education has concluded.

### **Benefit Three: Providing New Teaching Tools**

Technology enables teachers to create new tools to facilitate instruction. These tools can often prepare students for the world beyond the classroom, helping them develop higher-level thinking skills. According to OTA, “The process is as important as the product, as students develop skills in finding, evaluating, organizing, and communicating many types of information, using new technologies as well as traditional research methods.”<sup>15</sup>

### **Benefit Four: Accommodating Different Learning Styles**

If students are to learn to the best of their abilities, they must be taught in the way they learn best. Research on learning styles has found that most students are concrete learners who learn best through interpersonal communication, group learning, sharing, mutual

support, team processes, and positive reinforcement. Unfortunately, many schools continue to prepare teachers to use an abstract manner of instruction that requires students to think and watch, but does not give them the opportunity to do and feel. Few students respond to this type of instruction.<sup>16</sup> Teachers find that many modes of technology can be used to meet the educational needs of a variety of students, allowing them to work individually or in small cooperative-learning groups. Students can effectively learn, whatever their style.

### **Benefit Five: Redefining the Role of Teachers**

Technology—particularly the computer and high-quality software—enhances the opportunities for individual and group learning by providing students with a variety of resources and tools. Teachers, therefore, are allowed to assume the role of facilitator of learning rather than distributor of information. Many educational researchers find this role to be very beneficial to the learning process.

When used effectively, technology opens a world of possibilities for teachers and students. Effective applications of technology challenge students to use higher-level thinking skills and become active seekers rather than passive receivers of information. While a variety of technologies can be used in schools, some have proven more effective than others in encouraging students to solve problems, make active judgments, and apply learning to real-world situations.

### **Computer-Assisted Instruction Proves Ineffective**

In the past few years, research and common sense have targeted ineffective applications of educational technology—applications that fail to accommodate the learning styles of a variety of students. Among these applications is *computer-assisted instruction* (CAI), which involves students in uncomplicated “skill drills.” Computer-assisted drill and practice leads its participants into repetitions of exercises, requiring their mastery at lower skill levels before allowing them to move to more challenging practice. Drill and practice software is relatively easy to install and use and requires little teacher supervision. Both elementary and secondary schools have made great use of CAI drill and practice in the past several years because of its simplicity. As early as 1988, however, studies indicated that CAI was not preferable to teacher-led whole-group instruction. Nira Hativa of Tel Aviv University reports:

Sigal, a second-grade girl in Israel, was observed for several months while practicing arithmetic with a structured and controlled computer-assisted instruction (CAI) system. Sigal was average in arithmetic in her class, enjoyed the computer practice, and believed that it helped her arithmetic. However, observations showed that she consistently failed to solve problems on the

computer that she could do successfully with paper and pencil. She was therefore given CAI practice well below her real arithmetic ability. She often oscillated among a few types of exercises, sometimes regressing rather than advancing upward in hierarchical levels of practice. Several kinds of interventions did not bring about substantial improvement in her work with the computer. Continued observations in the following 2 years showed almost no change in her CAI-related behavior.<sup>17</sup>

Hativa recognized six software-related problems that hindered Sigal's success with CAI: a lack of remedial tutorials; mixed, rather than fixed, practice on specific skills; forced recycling of students through lower levels if they fail to master higher levels of skill; limited response time for solutions; the computer's capacity to only evaluate each digit as typed; and required mental performance of the intermediate steps of arithmetic problems. Through this study, Hativa concluded that CAI does not meet the needs of students who do not perform well under the technology's constraints—students with varying learning styles.<sup>18</sup>

In the same year, Hativa published more conclusions that supported her theory. Gerald Bracey describes Hativa's three-year study involving elementary students at the same grade level who demonstrated differing levels of ability. Those who were defined as high achievers at the start of the experiment mastered anywhere from 1.8 to 2.6 times more information than the low achievers.<sup>19</sup> Hativa wrote that these results:

. . . show that good students progress in solving difficult problems about two times faster than poor students progress in solving relatively easy exercises. The result is that the discrepancy in the levels between students with extreme abilities attending the same class grows continually with the years of CAI practice . . . When a student begins work with the computer system, he or she has to make an 'internal switch' from the regular mode of work with paper and pencil to the special mode of computer work. It appears that our low-achievers were not able to regularly make that type of on-and-off switch. These students showed less flexibility than high-achievers, thus making more software- and hardware-related errors.<sup>20</sup>

Even teachers themselves have identified the problems inherent in CAI drill and practice. A study was performed by teachers acting as "anthropologists" to explore some myths surrounding the use of computers in educational settings. For several reasons, the educators chose to interview other teachers to compare the myths regarding drill and practice to the realities of the classroom. Many of the researching educators had used drill and practice in the classroom and were disappointed with its impact. Others had read research concerning drill and practice and developed personal theories concerning its

ineffectiveness. All teachers were well qualified as researchers of the topic, being familiar with computer hardware and software and the instructional goals of drill and practice.

As the researching teachers predicted, the results of their study dissolved some of the currently popular myths concerning drill and practice. Gail Marshall, who published the teachers' findings, claims the results:

. . . sharpened [the teachers'] awareness of what students need in order to make sense of computer-based learning. They concluded that drill and practice use is not unidimensional . . . Above all, the field-workers questioned whether drill has the strong, positive impact on all students that the myths have conditioned us to believe.<sup>21</sup>

Among the myths the researchers explored was the following: "Computer classroom drill and practice is matched to students' diagnosed learning deficits, and by using the drill and practice software students improve their performance." They found that many teachers used only the software available at their schools, frequently relying on tools not designed to address specific learning difficulties. On the other hand, when drill and practice software that addressed learning styles was available, teachers reported that they often assigned the entire class to its use—even if a specific portion of the students needed no remediation.<sup>22</sup>

Yet another myth explored by the researchers addressed the assessment potential of drill and practice software: "Drill and practice software tests skills which students have acquired, provides feedback as a corrective when students make mistakes, and supplies teachers or students with a report on performance." Marshall notes that the "anthropologists" were more distressed with the reality of computer-provided feedback than with any other aspect of drill and practice-based CAI:

Many drill and practice programs graded a problem correct or incorrect, but provided no feedback on how to solve the problem correctly. The result? Many students [in a math class] continued to apply the wrong algorithms, so they practiced their mistakes during the drill session. In some cases our "anthropologists" watched the software provide the answer . . . [but] also saw the "Huh?" look on students' faces . . . As a result, the field-workers concluded that many students spend the 10-30 minutes of drill sessions practicing their mistakes.<sup>23</sup>

As studies indicate, CAI drill and practice does not adequately accommodate the differing learning styles of students. In addition, these programs usually fail to give students the feedback they need to truly learn from their errors. Because of these reasons, drill and practice is an ineffective means of educating many students. As another form of "one size fits all" instruction, drill and practice cannot address the needs of most individual

learners—the fact that it integrates technology makes little difference. Educational technology that fails to meet the needs of all students is of no benefit to schools, but rather a considerable waste of precious funding. Teachers cannot find a “quick fix” in technology. Boyle recognizes that “more than a few of our great intellectuals, as well as many of our local school boards, go with the flow of information, telling us that . . . what we need are more machines. . . .”<sup>24</sup> Unfortunately, technology’s solutions are not that simple.

### **Technology and Teachers: Where Do Educators Fit in the High-Tech World?**

Although schools have invested heavily in educational technologies over the past decade, most teachers still lack the knowledge desperately needed to facilitate learning through technology. OTA recognizes that these educators realize the importance of technology in their students’ futures, and worry that their lack of technical literacy will diminish the effectiveness of their efforts in the classroom. Nonetheless, schools continue to make only the purchase of technological equipment a high priority. OTA remarks:

It is ironic, then, that most teachers lack the knowledge to use and demonstrate these investments on an effective or even a functional level. It is also ironic that, despite their accessibility within the walls of schools, computers are still rarely integrated into the curriculum. By some estimates, fewer than 15 percent of all teachers in the United States actually use computers in their teaching.<sup>25</sup>

Today’s teachers, who face diverse real-world concerns from the presence of weapons and drugs on school premises to the decline of student attendance, are not to be held accountable for schools’ misdirected efforts to bring classrooms into the twenty-first century. Community leaders, administrators, and parents have been deluded by the concept of technology as a “magic potion” for education’s maladies. Unfortunately, many teachers feel that technology only provokes the anxiety they feel in a rapidly changing educational environment.

Educators have indicated many reasons for the difficulty of integrating technology into curricula. In many cases, schools purchase complex equipment for classroom use without providing teachers with professional development time to learn equipment operations and applications. In other situations, educators worry that integrating technology will upset established, accepted curricula. Still others fear that technology will minimize the role of teachers in the classroom, depriving them of student contact and the sense of accomplishment that can result from a career in education. Therefore, these reasons for the difficulty in integrating technology into curricula result in teachers remaining passive, standing silently by as technology performs its functions in classrooms. Unfortunately, technology

integration requires active involvement of teachers. Robert McCarthy, a researcher focusing on the issue of teacher preparation in the Information Age, asserts:

[We] must be wary of the dazzling effects of the computer's power and potential. As one computer coordinator puts it, "Many of us were so bedazzled by the computer when it first came out that we assumed the revolution would occur itself, almost by magic, as soon as the computers got through the classroom door."<sup>26</sup>

Unless they are consulted and provided with adequate guidance, no amount of time or money will encourage teachers to integrate technology into curricula. McCarthy remarks, "If the object is to integrate the computer into the curriculum, user-friendly may not be enough. What we need is teacher-friendly."<sup>27</sup> Because of this, he asserts that "Administrators, and software and hardware developers, are going to have to canvass the opinions and accommodate the wants and needs of the people behind the desks."<sup>28</sup> At the present time, educators, administrators, and specialists hold views like the following concerning teacher needs and technology:

- After you find out all about the technology and its capabilities, then you must find out what the teachers think. Teachers are the bottom line, the keystone of this whole revolution. We must find out what teachers want, and then determine if the computer can provide a solution. Throwing technology at educators hasn't worked, obviously; though it has informed us that computers aren't self-evidently pedagogical devices. —*Doris Ray, director of Maine's Computer Consortium.*<sup>29</sup>
- I'll tell you one thing [teachers are] saying. They're saying they are sick and tired of hearing about 'newer,' 'faster,' 'more powerful,' technological innovations that do nothing to increase ease of use. In fact, innovation almost always means great complexity of operation. What teachers want to hear about is simplification, and I am talking radical simplification. *Simplified instruction*—no unreadable manuals and long in-service training. Extreme ease of use and lots of fail-safes in case the wrong button is pushed. Teachers can't take the time in a classroom to just stop teaching and spend minutes and minutes getting something up on the terminal. It's got to be bang, bang, point, click. The problem is that computer vendors know a lot about the mechanics of hardware and software, but nothing about the mechanics of teaching. —*Brian Page, Assistant Superintendent of Instructional Services, Alpine School District, American Fork, Utah.*<sup>30</sup>

- When the courseware is able to deliver the information, then the teacher becomes able to deliver a lot of individualized instruction, and that is what will change the face of teaching. The secret is lots more, significant, better courseware. We need to get to the point where the computer can do what it does best and the teacher can do what he or she does best. —*Jim Dezel, Vice President and General Manager of IBM's Educational Systems Division.*<sup>31</sup>
- We all made a serious mistake in giving the computers to the kids first. We ignored the teachers, cut them out of the loop, and that's precisely the way to kill a promising educational technology. What we did was put computers in a lab and said, 'Here, use them.' What we should have done is given the computers to the teachers and said, 'Here, take them home and learn to use them.' —*Tom Snyder, administrator.*<sup>32</sup>
- I'm the old fashioned type—after so many years, you build up a file on your subjects . . . for me to go into teaching computers . . . I would have to actually sit down and work everything out, and it would require a lot more work on my part to run a class the way I want it to run . . . I just don't want . . . to change . . .<sup>33</sup>

One of the worries visiting “technophobic” teachers is that of performance anxiety. The act of teaching involves performance, and traditional teaching performances run smoothly when the tools of chalkboard and eraser are used for demonstration. Technology is more complex, and thus less predictable, than established teaching tools. McCarthy describes the following scenario as common to educators:

Imagine yourself a teacher, facing 30 or 40 little bodies. They're all staring back at you, your students, waiting for you to tell them something. Some, of course, would be delighted if you made a mistake or messed up. Nothing is funnier to students than a teacher messing up.<sup>34</sup>

OTA reports a similar comment from a teacher:

You can't have trouble or be messing with the machine in front of a class. It may be due to my lack of confidence, but I have to be comfortable with it if I'm going to use [it] . . . My computer phobia, I'm actually over that. I'm not afraid of using the machine anymore, like I was, but I am afraid of how they [the students] might react.<sup>35</sup>

For teachers to feel comfortable with computers and other technology, they must be provided with adequate experience in operating equipment—before the equipment is to be used in class. In some areas, like the Lake Washington school district in Kirkland, Washington, computers are given to teachers willing to participate in training workshops. Since this initiative (which allows the teachers to take the computers home, use them in

any way they choose, and borrow software from the district's software library), computer instruction in the schools has increased dramatically.<sup>36</sup>

Yet another anxiety teachers harbor about technology concerns the future role of the educator in a technological age. McCarthy asks:

Theorists and vendors casually speak of the technological transformation of teachers into "monitors," "facilitators," and "guides." How do teachers feel about such transformations? Will the computer intervene between the teacher and the traditional joys of teaching? Or, instead, will the computer open up new possibilities for teacher satisfaction—such as the prospect of more one-on-one instruction?<sup>37</sup>

These concerns must be acknowledged by administrators if teachers are to become comfortable with technology. While some educators fear the level of involvement technology requires from them, others worry that technology will eventually minimize the role of the teacher. Says James Bosco, director of the Tate Center for Research and Information Processing at Western Michigan University:

I'm convinced there is a role for the teacher in the technologized classroom, that falls somewhere between being the sole source of information and being nothing but a functionary who sees to it the kids stay on their computer tasks. But what we have to do is think these new roles into being; experiment with structures until we find them.<sup>38</sup>

Finally, teachers are concerned with the lack of support available to them as they learn to work with technology. OTA finds that, in a majority of schools, no support staff is officially assigned to coordinate or facilitate the use of technologies and that, in schools where a technology coordinator exists, most of his or her time is spent supervising students or selecting and maintaining software and equipment. Little of a technology coordinator's time is devoted to training or helping teachers use technologies.<sup>39</sup>

Another study indicates that less than half of American schools surveyed offer an introductory course for teachers working with computers.<sup>40</sup> This pattern is particularly prevalent in middle schools, where only 27 percent of schools offer a training course, as compared with 51 percent of high schools and 43 percent of elementary schools.<sup>41</sup> Overall, far more of education's technology expenditure is allocated to hardware and software than to teacher training or technical support.<sup>42</sup>

Several barriers exist between teachers and the integration of technology. Only time, determination, and flexibility will aid teachers as they attempt to adjust their classrooms and roles to the Information Age. According to McCarthy, Exhibit One highlights a few measures that can facilitate the process.

### **McCarthy's Ten Steps to Curriculum Integration**

1. Concentrate on integrating computers in areas where traditional teaching strategies aren't working or in areas where computers have already helped.
2. Find out what the teachers want and then determine if the computer can provide a solution. Don't just throw technology at teachers.
3. The technology must become much simpler—some say “radically” simpler—than it is today.
4. The proper software to teach curriculum courses must be developed; software that allows the “computer to do what it does best, and the teacher to do what he or she does best.”
5. There must be better communication between software vendors and teachers to help teachers sift through the enormous amount of software on the market.
6. There must be more and better teacher training—at the in-service and pre-service levels.
7. Teachers' colleges and schools of education should offer courses in integrating computers into the curriculum.
8. Give computers first to the teachers, then to the students. Let the teachers learn how to use them first.
9. The teacher must be convinced or shown that the computer will enhance the student's learning experience and also the teacher's teaching experience.
10. The role of the teacher—and traditional pedagogy—may have to change if computers are to be successfully introduced into every aspect of the curriculum.<sup>43</sup>

### **Exhibit One**

When it comes to technology, most teachers are still strangers in a strange land. Learning to use technology can be a very intimidating experience. By acknowledging educators' concerns, and seeking their input, schools can make their transition to technology considerably less traumatic. J. Howard Jackson describes the feelings of many educators as he remarks:

As I look at our profession as educators, I sometimes feel like Dorothy—I am confused by a sense of adventure that says the future holds untold miracles brought on by the changes in office technology and the sense of homesickness for the days back in Kansas when the transcription teacher taught students proper grammar, when shorthand was a marketable skill, and when we could pick up the telephone and talk to a person instead of a machine . . . The computer has changed every facet of our lives. It has also changed what we teach, how we teach, and who we teach. Some of us are still back in Kansas, and we are saying,

“No need for me to learn this stuff. I will soon retire.” Yet computer literacy is a must in the workplace.<sup>44</sup>

### **Distance Learning: A Brief Overview**

Of all the equipment facilitating educational technology, television is one of the tools most readily available to schools. OTA finds “Nearly every school in the country has at least one television set for instructional use . . . As of 1991, the typical school had seven television sets . . .”<sup>45</sup> The simplest but often least effective use of school television is the transmission of “talking heads,” or where the teacher stands in front of the camera and lectures to a group of students at a remote site. One-way televised instruction can be relayed to students through satellite, networks, or film. Talking heads have been a popular option in rural school districts and oversized universities because they increase the availability of instruction by qualified instructors to students everywhere. The reasons for televised instruction’s popularity are many: It is easy to install, is relatively inexpensive, and requires little supervision. Unfortunately, talking heads also have their drawbacks—they treat all their students exactly the same, being no more effective in addressing the differing learning needs of their students than droning lecturers. In fact, students may pay even less attention to talking heads than they do to real teachers; since there is little risk of being called upon by a one-way television. Thus, many students may experience less benefit from this method of instruction than from observing a live teacher. Frank T. Boyle suggests that the student who attends school “for the dynamic of instruction and who receives instead a canned lesson . . . is being cheated. A textbook lesson transferred to film might look more like real teaching, but it is probably of even less value . . .”<sup>46</sup>

Two-way audio and two-way video technology has the potential, however, to make a real impact on education in the future—bringing personalized, interactive instruction and invaluable “nearly real” experiences to students everywhere. Distance learning, like simple televised instruction, brings better learning opportunities to many students. Unlike televised instruction, however, distance learning enables students to interact with instructors through two-way video and two-way audio communication. According to Charles Schlosser and Mary Anderson, “Students learning at a distance have the potential to learn just as much and as well as students taught traditionally.”<sup>47</sup> Distance learning is most often used by schools in remote or rural areas and by schools that lack traditional educational resources, such as a qualified teacher for a low-enrollment course. Distance learning technologies also allow schools to offer advanced courses that would not be available otherwise. For instance, secondary students involved in some distance-learning programs can participate in college courses at the high school site.

Although definitions of distance learning vary, Desmond Keegan identifies six main elements that comprise any such effort:

- the separation of teacher and learner, which distinguishes it from face-to-face lecturing;
- the influence of an educational organization, which distinguishes it from private study;
- the use of technical media, usually print, to unite teacher and learner and carry the educational content;
- the provision of two-way communication, so that the student may benefit from or even initiate dialogue;
- the possibility of occasional meetings for both didactic and socialization purposes; and
- the participation in an industrialized form of education, which, if accepted, contains the genus of radical separation of distance education from other forms.<sup>48</sup>

The use of distance learning in K-12 settings has increased considerably in the last several years. OTA reports that in 1987, fewer than ten states were participating in distance-learning projects; today, nearly every state is involved in some form of distance education. In addition to distance learning for student instruction, many states and districts use the technology for videoconferencing, teacher training, and professional development.<sup>49</sup>

The Careers Unlimited Program at Linn Technical College in Missouri is only one of many successful distance-learning programs. Through a variety of methods, the program seeks to encourage both young women and young men to enter nontraditional career fields. In the past four years, the program's *Changing Channels* satellite teleconference series has enabled teenage girls to interact with women employed in high-tech, nontraditional occupations. The series, which is produced by the Satellite Learning Network, attempts to encourage the girls to consider modern workforce trends as they plan for future careers.

One *Changing Channels* teleconference featured women who work behind the scenes in the Hollywood film industry as producers, directors, cinematographers, editors, and writers. Another teleconference depicted the Kennedy Space Center in Florida and provided time for student interaction with Dr. Linda Godwin, a space shuttle astronaut. This teleconference also featured footage on *Principles of Technology* and *CORD Applied Mathematics* programs filmed at vocational schools and community colleges throughout Missouri. The footage explained the importance of applied academics courses to students interested in high-tech careers.

All *Changing Channels* teleconferences have been taped for future viewing, and these recordings continue to benefit high school sites and public broadcasting stations across the country in an asynchronous format.

### **Talking Back to Television: Instructional Benefits of Two-Way Audio and Two-Way Video Telecommunication**

Distance interaction is facilitated through a variety of equipment. Some distance-learning projects incorporate voice-only interaction through telephone lines. Students benefit from voice interaction when it is used for brief, question-and-answer sessions with instructors, but it is not as effective as video configurations for long-term instruction. For several years, students have participated in courses through live, one-way video and two-way audio transmissions. The students participating in these courses see and converse with instructors, but instructors cannot observe their students. Still other distance-learning projects involve two-way audio and two-way video communication that closely resembles face-to-face instruction. Gregory Jordahl explains:

[With two-way audio and two-way video], every classroom is equipped with a group of television monitors and a video camera generally positioned to tape all the students in that class. The lead classroom may also have additional cameras for teacher use. The teacher (or a technician) controls the video images that appear on the monitors through the cooperative. For example, the teacher might transmit her image on one monitor and an image of the chalkboard, an overhead transparency, or a lab demo on another. When a question comes in from a remote site, the teacher can transmit an image of the student asking the question on yet another monitor. In effect, every participant can see and hear every other participant—just as they would if they were all in the same room.<sup>50</sup>

At Murray State University in Kentucky, two-way interactive technology is a reliable way to offer business courses at multiple sites. All classrooms are equipped with teacher stations, monitors for student viewing, a monitor for instructor viewing, and external speakers. Instructors teach from each remote site at least once during the semester, and designate proctors to supervise examinations. In addition, instructors rely on technicians at the teaching site who manage system failures as well as audio and video quality.

The university's experience with two-way interactive technology has been favorable. Students agree that this alternative learning environment has challenged their abilities to adapt, and teachers find that some adjustments in teaching style are necessary for effective distance instruction. As the semester progresses, however, both students and instructors become accustomed to the interactive classroom environment. Students indicate that the enthusiasm of instructors works well in encouraging viewers at all locations to participate in class discussion. Most of the students prefer participating in the

interactive courses over traveling to campus, and establish friendships with students at all remote sites. Finally, the students benefit from a definite savings in time, money, and physical energy.

Murray State's two-way interactive instruction program is only one of thousands of initiatives of this kind across the nation. Two-way interactive courses provide an effective solution to any institution that seeks to educate more and diverse populations, but is constrained by financial concerns and location.<sup>51</sup> In fact, a study conducted by the North Central Regional Educational Laboratory (NCREL) in 1994 indicates that two-way audio and two-way video instruction is among the most effective and high-performing applications of technology in education, engaging students in the learning process rather than allowing them to become passive learners.<sup>52</sup> Unfortunately, two-way video telecommunication is more expensive than other interactive configurations; therefore, most schools rely on cheaper, low-performing technologies. OTA finds:

In about 70 percent of the districts with distance learning capabilities, two-way interaction is limited to voice-only interactivity through dial-up telephone lines, an arrangement that allows only a small number of participating classrooms to communicate on-air with the studio video instructor for a given class period. About 20 percent of districts' distance learning employs two-way video.<sup>53</sup>

Two-way audio and two-way video telecommunication, with the access it can provide to quality learning experiences, has considerable educational potential. Most schools, however, are not equipped with two-way audio and two-way video or other technologies that can maximize learning opportunities for all students. NCREL remarks of the evidence favoring high-performing technologies like two-way audio and two-way video:

This [evidence] raises the question: How can we justify the added cost and effort to install high-performance technologies if engaged learning can be attained without technology or with less expensive, low-performance technologies? We would argue that high-performance technology adds very substantial, qualitative differences to the learning environment that cannot be obtained without that technology. Indeed, the high-performance technologies . . . redefine many of the parameters that define schooling: where learning takes place, what constitutes the learning community, who is the teacher, who is a learner . . . Finally, such technologies address issues of equity in that they significantly redefine opportunities to learn for students who are poor and lack local resources and for students who are academically at risk and might otherwise be assigned to low-level tasks.<sup>54</sup>

As the costs of technology recede in the years ahead, education will experience a dramatic increase in effective implementation opportunities. During the past two decades alone, we have witnessed a surprising growth in the availability of technology for personal as well

as institutional use. Global access to technology has increased for two reasons. First, engineers have improved and downscaled equipment design and construction, making computers and other technologies more compact, portable, and suitable for individual use. In the 1960s, for example, the computers that stored and organized sizable amounts of data filled large rooms; today, a powerful computer can fit on a desktop. More importantly, however, declining costs have led to a stronger presence of technology in both the public and private sectors. As in any market situation involving supply and demand, the worldwide demand for technology has encouraged competition among companies desiring to enter this highly visible market. Personal computers, hardware, and software are now following the economic path of the calculator, with prices continuing to fall as more manufacturing competitors enter the high-tech market.

### **Concept and Applications Programs: Building Connections Between Learning and Life**

In the section entitled “Technology and Teachers,” this report discussed the obstacles—attitudes, fears, and lack of training—that inhibit teachers in efforts to integrate technology into classroom instruction. Research indicates that many educators are struggling to incorporate technology into activities more complex than the simple drill and practice of academic skills. Fortunately, the evolution of *concept and applications programs* brings an innovative solution to educators, requiring students to exercise academic skills and knowledge, technical literacy, and even higher-order thinking by participating in challenging, stimulating simulations and games. Students working with concept and applications programs not only learn how to use computers, but discover ways technology can assist them in life and on the job.

Concept and applications programs represent the culmination of technology as a teaching aid, encouraging users to rely not only upon stored knowledge, but also on uniquely human reasoning and problem-solving skills. Anita Cox remarks that these forms of technology will become more widespread and visible in response to education’s increasing need to prepare students for work in the Information Age:

Future educational software will be required to meet a broad range of educational objectives in a wide range of subject areas. Not only will instructional software designers and engineers be required to exploit the opportunities afforded by advanced technology, but also to provide sufficiently flexible tools to support end users across a broad range of course and subject domains. The result is that heavy demands will be placed on designers to incorporate basic principles from a range of salient academic disciplines, in particular, those of pedagogy, psychology, and computer science.<sup>55</sup>

Curriculum supplemented with concept and applications programs encourages students to develop higher-order thinking skills; skills they are usually allowed to sharpen only after attending to the less complex learning tasks of subject matter memorization and calculation. According to Solomon, Perkins, and Globerson, effective applications of computers make possible the activation of higher-order mental operations by relieving learners of lower-level operations and a heavy reliance on memory capacity.<sup>56</sup> Students working with concept and applications programs are required to solve problems that require a deep knowledge of informational concepts and applications. Lambrecht recognizes the timeliness of these programs as cognitive enhancers, remarking:

A . . . report from the Secretary's Commission on Achieving Necessary Skills (1991) responding to the America 2000 national goals identified three foundational competencies—basic skills, thinking skills, and personal qualities. The thinking skills included *thinking creatively, making decisions, solving problems, seeing things in the mind's eye, knowing how to learn, and reasoning*.<sup>57</sup>

Educational researchers agree that students appropriately prepared for the coming century must develop adequate problem-solving and reasoning skills. In *Education and Learning to Think*, Lauren Resnick identified the following benefits and characteristics of higher-order thinking, which is the culmination of today's exceptional, and tomorrow's indispensable, education.

- Higher-order thinking is nonalgorithmic. That is, the path of action is not fully specified in advance.
- Higher-order thinking tends to be complex. The total path is not “visible” (mentally speaking) from any single vantage point.
- Higher-order thinking often yields multiple solutions, each with costs and benefits, rather than unique solutions.
- Higher-order thinking involves nuanced judgment and interpretation.
- Higher-order thinking involves the application of multiple criteria, which sometimes conflict with one another.
- Higher-order thinking often involves uncertainty. Not everything that bears on the task at hand is known.
- Higher-order thinking involves self-regulation of the thinking process. We do not recognize higher-order thinking in an individual when someone else “calls the plays” at every step.
- Higher-order thinking involves imposing meaning; finding structure in apparent disorder.
- Higher-order thinking is effortful. There is considerable mental work involved in the kinds of elaborations and judgments required.<sup>58</sup>

Also citing the value of reasoning in this modern age, Roy Pea adds an additional “r” to the three considered components of any acceptable education:

One consequence of the information age is that what children will need to know to learn and develop will be drastically different from what our educational system now provides . . . Cognitive skills of information management; strategies for problem solving that cut across domains of knowledge; such metacognitive skills as planning, monitoring, and learning how to learn; and communication and critical inquiry skills will come to be valued more highly . . .<sup>59</sup>

To conclude, concept and applications programs can be immeasurably beneficial to students in developing the higher-order thinking and reasoning skills required for work and continued learning in the coming years. Unfortunately, OTA finds that schools lack widespread availability of this variety of technological tool:

. . . [Studies indicate] that some of the more promising uses of computers by teachers and students—desktop publishing, mathematics instruction using analytic graphing and calculating software, information-gathering from CD-ROM encyclopedias or . . . databases—can only be accomplished in a limited way, if at all, on most of today’s school computers . . .<sup>60</sup>

Available data suggest that in secondary schools, computers are used relatively infrequently for teaching and learning in traditional academic subjects, far less than in classes focused on teaching students *about* computers.<sup>61</sup>

If students are to develop the reasoning skills they urgently need to work and thrive in the Information Age, not only must they learn how to use technology; they must understand the remarkable enhancements technology affords everyday work and life. No longer can humans function as mere receptacles for information—computers more than adequately serve that purpose. Rather, schools must encourage students to use the more complex qualities of their minds; reasoning and creative qualities that are unique to humans. OTA agrees, commenting:

The most common uses of technologies in schools reflect educational philosophies of instruction that view students as recipients of information dispensed by the teacher (or by the technology) and the acquisition of specific skills and knowledge. However, many technology experts feel that the real potential of technology lies in its capacity to support pedagogical approaches that encourage students to become active participants in their own learning and to acquire critical thinking skills and more complex understandings. . . . Right now, however, a gulf exists between the ambitions of technology experts and software developers and the practice of teachers in classrooms. Helping teachers use technology to facilitate different educational philosophies and teaching practices will require substantial change in curriculum, instructional methods, and teacher understanding.<sup>62</sup>

## The Internet in Classrooms: Current and Potential Use

Of all the technologies available to students, telecommunication networking is of greatest value for familiarizing them with the world beyond the classroom. Telecommunication networking includes the Internet and other means of shared communications. Today's popular "Internet" is an international collection of interconnected electronic networks that allow communication between computers on these networks.

A school desiring access to the Internet or other networks must be connected to a wide-area network (WAN), which allows computers at great distances to communicate with one another. OTA finds that, of the schools with networking capabilities, 49 percent have WAN; 35 percent of those have access to the Internet, and 14 percent have access to other types of wide-area networks, such as *America Online*, *CompuServe*, or *Prodigy*. Unfortunately, only 3 percent of schools with Internet access make the access available to students and teachers in instructional areas. Thus, it is the administrators who usually benefit from Internet services.<sup>63</sup>

Educators with Internet experience confirm that greater telecommunication availability to students is a must for schools that want to provide timely education. Teachers who have access to telecommunication resources in the classroom readily describe the ways the resources open a new world of learning for students:

- "Electronic networks bring real equality of education to all students. My inner-city students were learning and participating with private school students who have access to very specialized equipment. Through Internet, my students were unaware of the social status of these students. It was wonderful to watch them exchange scientific information with students they would be very uncomfortable with in the classroom."
- "It has expanded our classroom . . . blown away the walls . . . filled us with a sense of possibility . . . made us less provincial . . . personally involved us with the nation and the world."
- "We're more keenly aware of a world outside the classroom, in the sense of being able to reach out to information resources and not operate in a vacuum."<sup>64</sup>

Some networking projects are initiated by individual teachers on a class-by-class basis. Increasingly, telecommunication-using teachers are finding that connecting to a "listserv" gives them immediate access to other classes sharing a common interest in a particular topic. For example, "GLBL-HS" is a listserv created by two New York teachers for multi-school discussions of world cultures.<sup>65</sup> Another example of the motivating effects of technology is described by a teacher in an alternative high school using a software simulation program as both learning tool and behavior motivator for ten 16- to 18-year-old students:

These students, referred from their regular schools and placed in the alternative school as a last chance before placement in a more restrictive educational setting, were often unruly and needed to develop social skills as much as they needed the academic skills they had missed in their earlier schooling experiences. Engaging this group was a challenge; yet, almost all were enthusiastic when presented with a science activity using simulation software. According to this teacher, his students loved working with “The Great Solar System Rescue,” working in teams as “experts”—meteorologists, astronomers, geologists, and space historians—they were all challenged to find lost probes in the solar system . . . When one student became disruptive in the class, his punishment was not being allowed to participate with the team for several days. The teacher said it was one of the most effective behavior modification techniques he had ever used.<sup>66</sup>

Yet another situation where a telecommunication network aids a science educator can be found in Eden Prairie, Minnesota. Jeff Holte’s Central Middle School students grow corn, track geese, measure acid rain, monitor weather patterns—and compare their findings with those of students across the United States.

Holte uses MIX, the McGraw-Hill Information Exchange, an on-line network, to help him conduct the science projects. He also uses the National Geographic Society’s Kids Network and local bulletin boards as well. With telecommunications, Holte’s students perform real experiments, use real data, and have a real community of other young scientists with whom to share information. . . .

This past January, for example, Holte’s students grew corn from seeds . . . as part of a national corn growing contest. MIX sent them and other participating schools the seeds, maps of the United States, and charts to monitor growth.

Students researched soil types in preparation and carefully planted, watered, and fertilized their crop. Then they watched the seedlings grow and recorded the amounts of water, fertilizer, light, and location. Most important, they charted the size of the corn. They posted this data regularly on the MIX “Plant” electronic conference.

Each class used reports from all of the other sites. They monitored and compared seedling growth around the country, plotted and interpreted maps, and wrote to one another on-line to compare notes.

. . . But, he [Holte] says, “The students learned things they will always remember because they did true comparisons of real live information.”<sup>67</sup>

This and other demonstrations of telecommunication networks prove that they are valuable, effective tools to facilitate learning. Unfortunately, one of the issues delaying

nationwide acceptance of networks in schools is that of student protection. In addition to the wealth of information available through networks are a multitude of images and literature not suitable for young audiences. One news article noted:

The cyberspace battles may prove especially contentious, because the Internet contains a great many works not found on the shelves of most schools. *The School Stopper's Textbook*, for instance, tells how to short-circuit electrical wiring, set off explosives in school plumbing, and “break into your school at night and burn it down” . . . Schools can keep a pornographic book off the library shelf by not buying it, but they can't keep it from entering the building through cyberspace.<sup>68</sup>

OTA finds that schools approach the problem of student protection in a variety of ways. Some schools restrict telecommunication access to teachers and administration only. Other schools afford students responsibility for their actions by setting guidelines for acceptable “surfing” and rescinding privileges of students who violate the guidelines. Still other schools rely on solutions that block access to certain areas of network information.<sup>69</sup>

Telecommunication networking is fairly new to the educational arena. Educators, students, and parents have had less than a decade to become adjusted to the overwhelming amount of information the Internet and other networks can provide. Issues of student protection and censorship can be resolved only by more years of trial and error. Ironically, the capabilities that worry parents are the very capabilities that thrill educators as they introduce students to the world beyond the classroom—and provide meaning and context to the students to answer the question, “Why do I have to learn this?” Thus, telecommunication networking must become available to all students preparing for a world, and a workplace, where information is key.

### **Implications of Research on Technology Use in Education**

The previous sections of this report review current research regarding the effectiveness and potential of computers and telecommunication technologies as teaching and learning tools. The studies reviewed in this report indicate that the mere presence of technology in classrooms cannot transform education; rather, effective integration of technology must require users to exercise problem-solving and creative abilities as well as academic skills. Most educators lack the training and knowledge to effectively integrate technology into curricula, and are concerned that this disadvantage is negatively affecting the quality of American education. Several technologies, when properly implemented, show promise as valuable educational tools: distance learning via two-way audio and two-way video telecommunication, the Internet, and concept and applications software. These tools, in

conjunction with relevant, thorough professional development for teachers, can make American classrooms environments for successful Information Age education.

In reviewing current research, CORD determined several issues relevant to the integration of technology in education and workforce preparation—issues that must be addressed in more depth by researchers. This organization views these issues as extremely pertinent to the future of technology in education, understanding that the way these inquiries are addressed will directly affect the degree to which new technology will enhance and increase teaching and learning opportunities.

**Question One:**

What specific elements of computer software programs most effectively enhance the learning experience?

**Question Two:**

Is it possible to develop effective software that incorporates the proven pedagogies of cooperative learning, higher-order thinking, integrated learning, and multiple intelligences, while using real-world applications of mathematics and science concepts?

**Question Three:**

If software incorporating the proven pedagogies of cooperative learning, higher-order thinking, integrated learning, and multiple intelligences, and using real-world applications of mathematics and science concepts, can be developed, will it prove effective in actual classroom settings?

**Question Four:**

Is it possible to deliver, via two-way audio and two-way video telecommunication, meaningful, real-world worksite learning experiences?

**Question Five:**

If effective worksite learning experiences can be delivered via two-way audio and two-way video telecommunication, to what degree can they improve student understanding of the world of work and its relationship to the mathematics and science concepts learned in the classroom?

**Question Six:**

If distance education via two-way audio and two-way video telecommunication is an effective method for teaching and learning, how can professional development

opportunities, including on-time coaching, experiments, demonstrations, and discussion groups, be effectively provided to educators, business, and industry?

**Question Seven:**

What are the most effective uses of the Internet for enhancement of mathematics and science instruction?

**Question Eight:**

How can teachers be prepared to use the Internet and other telecommunication networking to enhance mathematics and science instruction?

CORD is currently attempting to address four of these issues with efforts designed to assist educators in effectively integrating technology. These research and development projects, which respond to teacher needs implied in questions one, two, four, and six, are described in detail in the following section. Questions three, five, seven, and eight indicate issues not yet addressed by our organization or others, but will undoubtedly command equal, timely attention as our nation strives to prepare students for the demands of the Information Age.

**Response to the Research: The Integration of Technology  
into CORD Curricula**

As a not-for-profit organization dedicated to preparing all students for the future workforce, the Center for Occupational Research and Development (CORD) acknowledges and respects the current findings on technology in education. Since the organization is devoted to excellence in education and training for work through contextual curriculum materials and processes, CORD has adopted a learning-focused approach to the development of educational strategies, products, and services. CORD's researchers and developers believe that all students can learn; that students possess individually distinct learning styles; and that students learn best when they are taught through methods that suit their individual learning styles.

The first section of this report included information indicating that technology in and of itself does not facilitate learning. Rather, effective applications of technology require the imagination and interest of well-trained instructors who understand how technology can be integrated into curricula. The staff of CORD seeks to assist educators in effectively and appropriately integrating technology into applied academics instruction. Because the computer is a premier workplace tool of our time, and also because applied academics teachers have requested our assistance in technology integration, this is a welcome and timely initiative.

As advocates for “hands-on” contextual instruction, CORD believes that technology can bring theory to life, showing students the real-world applications of their efforts in learning. Technology’s capabilities bring unique qualities to the classroom, making certain kinds of simulation, calculation, and visualization common to Tech Prep instruction more tangible and thus more understandable. Simply put, technology makes learning easy for students with a wider range of learning styles, and can show all students a world beyond the classroom walls—regardless of their career goals or socioeconomic status.

In consideration of the current research on technology-aided education, and to assist schools in integrating technology into CORD’s applied academics curricula, CORD has initiated four ongoing research and development projects: a review of on-the-market software, creation of CD-ROM computer software, implementation of a network of two-way audio and two-way video to foster work-based learning, and the creation of a virtual teaching center. These developments will be explained in further detail on the following pages.

### **Question One Research and Development Project Summary**

**Question one: What specific elements of computer software programs most effectively enhance the learning experience?**

What does computer software actually do for students and teachers? The purpose of using any learning technology, including software, for teaching and learning is to facilitate the access, assimilation, and production of information. In the case of software, especially the new multimedia software, it may be somewhat easier to be led astray from this pedagogical purpose than with other technologies. Software is abundant in the school marketplace; teachers are bombarded with enticing new titles and marketing promises. Moreover, the new programs are very appealing to the senses; many boast television-quality graphics and video style that matches that of modern advertising. Sometimes, it is difficult to identify the teaching strategy beneath the glitz.

To keep up and select effective software for classroom use is itself a time-consuming and sometimes confusing task. CORD has undertaken the task of surveying mathematics, science, and career software aimed at the secondary and postsecondary markets. Our primary goal has been to create a framework for educators to use in evaluating and selecting software based on the specific element of how the software is to be used in the learning process. However, this goal is not related merely to buying; clarity of selection is seen as inextricably linked to appropriate use.

### **What is the software triangle?**

The core of CORD's framework for software evaluation is a triangle, dubbed the software triangle. Its three angles and its center together represent four fundamentally different functions of currently available software. We have characterized these functions as follows:

***Open-Ended Tools.*** Programs for word processing, spreadsheets, graphics, and so on, give the user powerful tools for manipulating information. Their use for synthesis and presentation of information to others makes them educationally effective. (The ability to teach others has been shown to be a highly effective learning and assessment strategy, associated with over 90-percent retention and understanding.) Also, the use of information-processing software is a workplace skill and has intrinsic meaning and motivation for students.

***Drill-and-Practice Programs.*** Drill-and-practice programs provide questions or problems, often in multiple-choice format, and programmed responses to right and wrong answers. These programs sometimes provide concise bits of information or instruction, requiring the user to "practice" by feeding back that information. Of the four types, drill-and-practice programs have long been the most familiar to many classroom teachers. Parodied by some as "drill-and-kill" programs because of their rote character, these programs are generally considered the least effective for the teaching of higher-order thinking skills, problem solving, information retrieval, collaboration, or other skills highly valued for lifelong learning and success in the workplace.

***Concept and Applications Programs.*** Concept and applications programs allow the user to explore and apply concepts, often in a simulation or game. Fewer of these programs are available relative to the other types of software. Among the best-known examples of concept and applications programs are the Sim series programs; they include *SimEarth*, which models biogeochemical cycles, climate changes, and other forces that affect the planet, and *SimLife*, which models natural selection over time.

***Information Resources.*** Information resources, or reference tools, are placed at the core of the software triangle. These are primarily the multimedia encyclopedias, dictionaries, and collections of information many of which are searchable through databases.

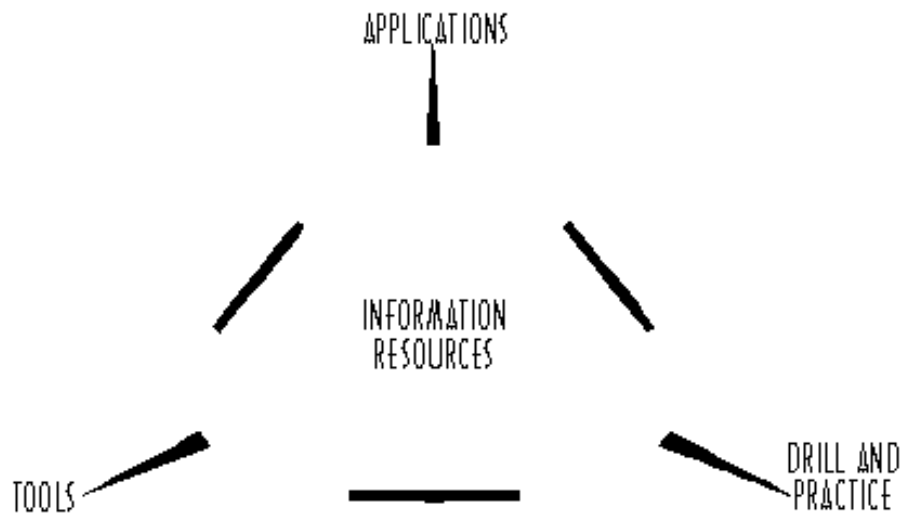


Figure 1. Software Triangle—a model for evaluating software for teaching and learning

The software triangle can provide educators with a ready framework for analyzing how a program functions. For example, a program such as *Interactive Physics* provides some information. It is extremely open-ended and serves as a tool for teachers and students to use in posing and solving physics problems. Thus, it is placed near the tools angle of the triangle, but also is slightly toward the center of the triangle because it provides information (Figure 2). By contrast, a word processing/spreadsheet/database program such as *ClarisWorks* is positioned near the outer edge of the same left angle of the triangle. An encyclopedia such as *Compton's Interactive Encyclopedia* fits into the middle of the triangle; a simulation program such as *SimLife* belongs on the top of the triangle; and a program such as *AlgaeBlaster* belongs in the drill and practice area on the right side of the triangle (see Figure 2).

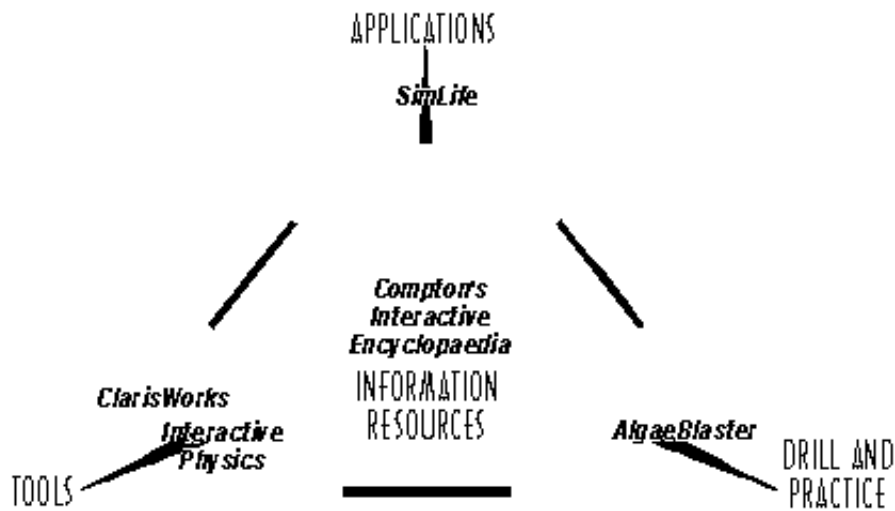


Figure 2. Software triangle with several programs identified within

### **What questions need to be asked about educational software?**

The software triangle is a guide for orientation. It gives educators an entry point to evaluate software. Beyond the general identification of the function of software, though, many questions need to be asked. A full treatment of these questions is beyond the scope of this paper; however, two sets of issues are the focus of examination at CORD.

#### ***In what learning activities is the student engaged while using this program?***

Activities may include any of the following:

- communication (writing, speaking, drawing)
- research or investigation (retrieving information)
- organizing information (sequencing or sorting into categories)
- problem solving
- creative thinking
- interdisciplinary thinking
- cooperative learning
- hands-on learning
- contextual learning

#### ***How is the program designed and presented?***

Factors considered in this determination include the following:

- interactivity
- production quality
- entertainment or interest
- age level of appeal

- gender and ethnic equity and diversity
- reading level required

Teachers and other educators may benefit from using checklists or a questionnaire in evaluating software. CORD has developed a teacher questionnaire for use in the Learning Technology Center of the Maurice W. Roney Teaching Center. The CORD survey includes checklists such as the ones listed above as well as more open-ended questions. A checklist of learning activities can be helpful in identifying the precise instructional objectives addressed by the software. It helps the teacher answer the question: What will my students be doing with this software?

A checklist of the design and presentation issues can help teachers determine the appropriateness of a particular piece of software for the student audience. Issues such as the entertainment quality and production quality are serious considerations for an audience of high schoolers long used to the clarity and special effects of television and film. Moreover, the new multimedia technology has raised the level of production quality and aesthetic excellence that teachers can reasonably expect in educational software.

#### **A final word: Who's in charge?**

With software, as with any new technology, human beings have to make good choices in order for the software to be used appropriately. The successful integration of software into the instructional process will take place only as teachers begin to take charge of software selection. Fortunately, more and more teachers, armed with knowledge about what specific elements of the software most effectively enhance the learning experience, are doing so.

#### **Question Two Research and Development Project Summary**

**Question two: Is it possible to develop effective software that incorporates the proven pedagogies of cooperative learning, higher-order thinking, integrated learning, and multiple intelligences, while using real-world applications of mathematics and science concepts?**

To investigate the issues surrounding question two, CORD has initiated a project to use available research regarding cooperative learning, higher-order thinking, integrated learning and multiple intelligences to develop hands-on multimedia CD-ROMs that use real-world, contextual applications of concepts. These programs will enable students to practice and apply mathematical concepts learned through secondary mathematics. Students, working with the programs individually or in groups, apply the mathematical concepts they have learned to real-world scenarios. Each multimedia CD-ROM places

students in a simulated scenario where mathematical skill is required to achieve game objectives. As they play, the students receive advice from a host of on-screen occupational advisors, including engineers, contractors, vendors, and city planners. The on-screen advisors provide students with directions and information that will assist them in making financial decisions and interpreting data; working with lines, angles, ratios, proportions, scale drawings, and two- and three-dimensional shapes; finding coordinates and correctly plotting them; and calculating formulas and deciphering mathematical expressions in test results. The first four software adventures are titled *Cyber Snacks*, *Gearing Up*, *Pooling Around*, and *Train Wreck*.

Students working with *Cyber Snacks* find themselves in a professional setting where they are challenged at one of two levels, “Learning Level” or “Real World,” to maximize sales for a fictional snack food vendor. The game prompts students to consider the effects of budgets, inventory, sales location, weather, and other constraints on the company’s profit from sales at a “Cyber Bowl” event. Participants in *Cyber Snacks* apply mathematical concepts, including estimation and the interpretation of charts and graphs.

*Gearing Up* is based on the sport of bicycle racing. Given a set of obstacles, participants working with *Gearing Up* design a bicycle race track and race the course. The software allows students to play in a multi-team simulation, either simultaneously or on multiple machines. At the game’s beginning, *Gearing Up* requires each team to construct one part of a race track whose construction will dictate other game challenges. Informed by an on-screen race official, the students consider specifications, such as angle size and length, for the track’s construction. Participants complete track fabrication by selecting a race setting: mountainous terrain, a desert area, or city streets. As they select gear speeds, roads, hills, and weather for racing, teams participating in *Gearing Up* are required to figure ratios and proportions and determine angles and slopes.

*Pooling Around* involves students in the simulated construction of a swimming pool. Participants must consider the constraints of a restricted budget and customer specifications when selecting appropriate materials, contractors, and skilled employees. *Pooling Around* requires students to solve problems created by realistic situations, such as the lack of available subcontractors, difficulties caused by underground electrical lines, and unforeseen weather changes. In addition, the participants’ customer always asks that the pool be completed in three weeks—regardless of weather, material availability, or other circumstances. Thus, participants are liable for additional costs they incur to complete the pool on schedule. As they seek to “construct pools” according to game guidelines, students working with *Pooling Around* software apply knowledge of two- and three-dimensional shapes. Determinations of pool depth, wall thickness, water quantity, and tile type and quantity are only a few of the considerations requiring participants to apply mathematical skills.

Finally, *Train Wreck* requires participants to respond to environmental hazard emergencies by applying mathematical concepts. Students figure powers, roots, and linear equations as they recommend solutions to circumvent the emergency: a train derailment resulting in a chlorine or ammonia gas leak, the rupture of a tank car holding diesel fuel, or the rupture of a car carrying radioactive materials. Successful teams must avoid causing further environmental damage, accurately interpret mathematical information, apply and calculate appropriate mathematical formulas, and effectively reclaim or rehabilitate the area. In addition, participants must handle unforeseen obstacles—weather conditions, bureaucratic red tape, and the like—that may hinder their efforts to protect the troubled area.

*Cyber Snacks*, *Gearing Up*, *Pooling Around*, and *Train Wreck* should enable students to practice and sharpen academic knowledge and skills and to work in cooperative groups to solve problems. These entertaining programs will simulate for students situations that require an adequate knowledge of mathematics. In time, students working with these programs should better understand the value of mathematical skills in the real world. As these programs are used in classrooms, the issues of effectiveness addressed in question three will need to be studied.

#### **Question Four Research and Development Project Summary**

**Question four: Is it possible to deliver, via two-way audio and two-way video telecommunication, meaningful, real-world worksite learning experiences?**

Through a cooperative effort of CORD, the Baylor University School of Education Professional Development and Technology Center, inner-city and rural high schools, AT&T, Sony, and other businesses, a model network of work-based learning has been established. Through this effort, a network of schools and key industry sites can lay the framework for modeling work-based experiences for students in both urban and rural schools. This research and development project will determine which experiences can be conveyed to the students through the use of telecommunication and multimedia technologies.

Students exposed to these experiences will see, hear, and interact through carefully selected and designed work-based learning experiences, and will participate as though they are shadowing a job or observing a workplace for the first time. In addition, these students will interact with employees who act as workplace mentors, demonstrating skill and knowledge in the workplace. Finally, the students can discover real-world uses for academic knowledge, technical skills, and soft skills in the workplace. In time, the

technology and procedures developed for this initiative should set a model for schools nationwide.

The following are features of the student experiences resulting from this initiative:

- clear connections between work-based learning and curricular concepts;
- high visibility of minority and female role models;
- collaborative, cooperative learning among students;
- technology use embedded in and integral to the learning process; and
- transmission of the workplace culture as well as introduction to work skills.

Through its strong development of educational systems that bridge the gap between school and work, CORD is designing, developing, and disseminating three major components of the technology integration project. The first component—a database of video, technology, business information, and tools—will provide a foundation for work-based learning experiences. An organized collection of these work-based learning experiences will serve as the second component; this project element will provide information and support to teachers and counselors through a Library of the Workplace. The third project component will bring work-based experiences to life for thousands of students—through live video teleconferencing. The teleconferences will involve the interchange of schools and businesses, and will disseminate the models and tools of work-based learning through the National Tech Prep Network (NTPN), a coalition of over 3,000 educators, employers, and community leaders supporting the development of education for the future workforce. NTPN will ensure the effectiveness of the teleconferences through the vast experience and knowledge of its members.

Following the full implementation of this project the groundwork will be in place to research question five.

### **Question Six Research and Development Project Summary**

**Question six: If distance education via two-way audio and two-way video telecommunication is an effective method for teaching and learning, how can professional development opportunities, including on-time coaching, experiments, demonstrations, and discussion groups, be effectively provided to educators, business, and industry?**

Since CORD's formation, our researchers and curriculum developers have dedicated their efforts to the preparation and ongoing professional development of educators everywhere. For years to come, CORD will continue to seek solutions that can aid teachers in their

efforts to transform education. In early 1993, CORD established the Maurice W. Roney Teaching Center (RTC) in Waco, Texas. This state-of-the-art, 7,000-square-foot facility features teaching laboratories for mathematics, science, and physics, as well as a fully equipped learning technology laboratory. Through the efforts of our professional staff and other outstanding educational practitioners, the RTC has served as a site for hundreds of educational presentations, seminars, clinics, and workshops during the past three years that have involved over 6,000 participants worldwide. Most of these activities have included in-depth, week-long courses introducing teachers to the latest techniques in contextual instruction and technology use in the classroom.

CORD has recently embarked on a further expansion of its commitment to the professional development of teachers in order to investigate the basic research issue in Question Six. In its initial implementation phase, our Virtual Teaching Center (VTC) has been designed to operate in conjunction with the RTC. The VTC is equipped with the latest in high-technology teaching aids, and will provide real-time two-way audio and two-way video communication and asynchronous professional development experiences to sites across North America and worldwide. CORD anticipates that this new capability will supplement our initiatives in professional development, field support, and technical assistance to educators, and offer the following means of support:

- just-in-time teacher training for CORD applied academics courses;
- train-the-trainer workshops;
- simultaneous workshops at remote receiver sites coordinated through the VTC;
- two-way communication between CORD's professional project staff and field practitioners; and
- other special projects to be announced.

The VTC equipment will also enhance many RTC programs that include distance-learning components.

As CORD focuses on Question Six, effective methods of providing professional development opportunities via two-way audio and two-way video technologies will emerge through experimentation and research. CORD expects the VTC to serve as an exemplary site in a widespread, virtual network of colleges of education, advanced technology centers, local school districts, and worksite learning centers in business and industry.

Questions seven and eight will remain research opportunities for CORD or other organizations to investigate in the future.

## Conclusion

As studies indicate, technology has the potential to enhance systemic educational reform in the coming years; reform that prepares all students for the world, and the workplace, of the future. Educators must be trained, however, in the methods of technology integration that serve students best. Although studies have not yet confirmed the best uses of technology in education, most educators who experience success have integrated technology in ways that not only measure student skills and abilities, but also encourage creativity and higher-order thinking among users.

In this Information Age, America's teachers must emphasize more than the basic functions of computers to their students. When effectively integrated, technology can be used as a tool to fortify learning experiences and bring meaning to education. Students working with effectively integrated technologies can discover the importance of teamwork and learn to use technology as an aid for future personal and professional growth. These experiences, in turn, prepare our nation's youth for the workforce they will soon enter; a workforce where reasoning, problem solving, and lifelong learning skills are requirements.

For educators to use the new technologies fully to enhance teaching and learning opportunities, they need conclusive recommendations about the effectiveness and best practices of new technologies. As a result of CORD's research on the use of technologies in education, eight significant questions surfaced that need further inquiry. CORD has already embarked on projects that focus on four of these questions.

Through the efforts of CORD, teachers can learn how to effectively integrate technology into curricula. Participating educators worldwide will have the opportunity to learn through the use of the Internet, two-way audio and two-way video telecommunication, and other emerging technologies. In addition, they may network and share curricula with fellow educators around the world. It is CORD's belief that these solutions will strongly aid schools as they attempt to prepare our nation's youth for the challenges of the Information Age and beyond.

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