Information technologies might improve learning and teaching in two distinct ways. Just as they have made workers more productive in business and commerce, they could reduce teaching costs or increase the speed with which learners acquire knowledge. Alternatively, such technologies might help improve the quality of learning, rather than simply making it faster and cheaper. In this section we first review evidence that information technologies can improve the efficiency of learning and teaching; then we consider how they might lead to better educational outcomes.

REDUCING COSTS AND INCREASING PRODUCTIVITY

Most discussions of computers in education look at how new technologies might improve “instruction delivery,” a management theorist’s way of saying how teachers teach and how learners learn. Therefore, as resources for higher education continue to dwindle, when most people think of information technologies, it will usually be in terms of how such technologies might reduce the number of teachers needed or cut the time (and money) it takes learners to acquire skills. A collection of cases in current practice suggests that some technologies do indeed help improve productivity in these ways. (See Figure 2.1.)

Current successes are subject to several qualifications. Some cost savings are modest, others come with hidden prices (for example, high development costs or lower graduation rates), and all depend
on careful attention to implementation in the classroom. But, although the data are still unclear, the economic logic behind the view is relatively straightforward: Cut costs by doing more with less; that is, hold student outcomes roughly constant (or improving) while displacing labor (staff) with capital (here, information technology). With technology costs continually dropping while labor costs only rise, this trade-off appears a good one for increasing productivity.

<table>
<thead>
<tr>
<th>Site/Study</th>
<th>Cost-effectiveness Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Computer-Aided Instruction (CAI) and Computer-Based Instruction (CBT)</strong></td>
<td></td>
</tr>
<tr>
<td>Orlansky and String (1979)</td>
<td>-30 percent reduction in time to achieve criterion performance using computer-based instruction in military training</td>
</tr>
<tr>
<td>Fletcher (summary of 47 studies) (1991)</td>
<td>-30 percent time savings, 30-40 percent cost savings, and improved achievement using multimedia instruction</td>
</tr>
<tr>
<td>Levin (summary of 8 programs) (1989)</td>
<td>-CAI proved more cost-effective than reducing class size or extending length of school day -but less effective than peer tutoring</td>
</tr>
<tr>
<td>Hall (summary of 8 case studies) 1995</td>
<td>-CBT in business reduced training time 40 to 80 percent compared with traditional text-based training -CBT in business reduced training costs 40 to 85 percent compared with traditional training</td>
</tr>
<tr>
<td>Roberts (1991)</td>
<td>-IBM cut its annual training budget (over $1 billion) by $30 million by using CBT</td>
</tr>
<tr>
<td><strong>Intelligent Tutoring Systems (ITS)</strong></td>
<td></td>
</tr>
<tr>
<td>U.S Air Force</td>
<td>-ITS traditionally deliver high student learning outcomes, but at a high price; the Air Force aims to cut development costs by 95 percent and development time by up to 80 percent -the result would be an overall reduction in training costs</td>
</tr>
</tbody>
</table>

Figure 2.1—Information Technology and Cost Savings (continued on next page)
### Distance Learning

<table>
<thead>
<tr>
<th>Institution</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open University, United Kingdom (1989)</td>
<td>- cost per graduate lower than conventional university’s</td>
</tr>
<tr>
<td>Deakin University, Australia (1989)</td>
<td>- cost per student 97 percent that of on-campus student</td>
</tr>
<tr>
<td>Indira Gandhi National Open University, India (1991)</td>
<td>- cost per student between 8 and 40 percent of cost at conventional university</td>
</tr>
<tr>
<td>- student performance rates only 60 percent</td>
<td></td>
</tr>
<tr>
<td>Open University teacher training, Indonesia (1988)</td>
<td>- cost per student about 60 percent of cost at conventional university</td>
</tr>
<tr>
<td>Everyman University, Israel (1978)</td>
<td>- cost per graduate estimated at one-half cost at conventional university</td>
</tr>
<tr>
<td>Teacher training at a distance, Tanzania (1979/1984)</td>
<td>- costs about one-half those at a conventional university</td>
</tr>
<tr>
<td>National Technological University, USA (1989)</td>
<td>- break-even point (in per-student cost) at 9,000 students in 200 courses</td>
</tr>
</tbody>
</table>

**SOURCES**: Distance-learning results summarized from Perraton (1994, p. 21); CAI and CBT results summarized from [http://www.whitehouse.gov/WH/New/edtech/perform.html](http://www.whitehouse.gov/WH/New/edtech/perform.html), except for Hall and Roberts results, which are summarized from Hall (1995).

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**CAI and CBT**

Computer-aided instruction (CAI) and computer-based training (CBT) have shown some ability to do more with less, by providing learners drill-and-practice systems that replace teachers in routine coaching tasks. These systems are most frequently found in secondary schools but also play a role in remedial math, science, and language courses at the collegiate level, as well as in business and military training (Figure 2.1). However, as convenient as they might be for self-paced learning, CBT programs often do not yield dramatic cost savings. Development costs for multimedia courseware are usually very high, often offsetting savings in delivery, and the price of a stand-alone computer system for each student is sometimes so dear that labor costs must fall dramatically before any net savings
appears. The latter situation may change in the future, however, as powerful machines drop roughly to the cost of a top-of-the-line TV.

Distance Learning

A few intelligent tutoring systems (ITS) also have reported cost-reductions in training. (See Figure 2.2.) But, as with CAI and CBT, development costs currently impose strong limits on their productivity gains. In fact, the main attraction of ITS is that they may improve the quality of learning rather than reduce costs, as we discuss later under “Increasing Quality and Productivity.”

Today, distance learning—whereby students and teachers rely on electronic and hardcopy media, rather than on face-to-face contact, for at least some of their communication (correspondence courses by postal mail are perhaps the oldest form of distance learning)—provides probably the best examples of cost savings that are at least partly attributable to information technologies. In this country, the PLATO system,\(^1\) among others, pioneered distance learning in the 1960s, connecting as many as one thousand student-terminals at a time to mainframes. Only relatively recently, however, have these trailblazing ideas translated into reduced education costs. Several studies (Figure 2.1) show that distance-learning courses in Asia cost from 45 to 90 percent of the cost of conventional college classes, with comparable student performance; costs can drop to as little as 8 percent of on-campus courses, although completion rates then also seem to dip. Using telecommunications to offer distance learning for over three decades, the Open University in Great Britain—one of the first very large-scale experiments in distance learning at the higher-education level—boasts average per-student costs of around one-half those of conventional campuses. (See Figure 2.2.) We briefly examine its success to show why, at least right now, distance learning can help reduce costs only under relatively narrow circumstances.

The Open University: An Example in Achieving Cost Reductions. First, the technology must allow many students to be taught at once. Class sizes at the Open University usually exceed 200. The larger the

\(^1\)For all its illustrious history, good discussions of the PLATO system are rare. One brief but broad history can be found at http://www.tencore.com/plato.htm.
The best-known example in higher education, and most successful example of its kind in the world, is the UK Open University. Some 40 distance teaching institutions across the world have been based on the OU model. Its methods are well known, but it is worth emphasizing an important aspect that is often misunderstood. Although the OU has developed widely admired methods for the use of teams in the design and production of teaching resources, mainly paper-based materials, and although it still carries in many people’s minds the image of the “University of the Air,” it is the UK-wide network of part-time tutors who provide the main teaching that is experienced by OU students. Tutorial support is provided by traveling to quite frequent face-to-face meetings, by telephone contact, and by feedback on written assignments. In a real sense, the formal aspects of studying for an OU degree differ little from those experienced by students on a conventional campus. The cost per student, however, is about one-half that of conventional campus universities. The OU is now exploring how best to build on its success through the emerging advanced learning technology (ALT), in particular the use of CMC (computer-mediated communication) for collaborative learning and the delivery of its course materials through CD-ROM (from Mayes, 1994; http://www.icbl.hw.ac.uk/ctl/mayes/paper10.html).

Figure 2.2—The Open University: Mother of Modern Distance Learning

class size, the greater the student–teacher ratio, which lowers labor costs and spreads high development and initial technology costs, leading, in turn, to productivity improvements. Break-even points—class sizes for which the cost of distance education and traditional delivery are roughly equal—will vary depending on, among other things, the size of technology investment and the course being taught. But it is a safe bet, at least for the near term, that distance-learning classes of less than 20 will rarely lead to substantial per-student cost reductions.

Second, a substantial amount of labor must be displaced by technology. Typically, labor is over 95 percent the cost of the class; so, modest trades of faculty for machines will not substantially change overall prices. Consequently, distance learning works best in relatively “standard” courses—math and the sciences—for which knowledge is relatively routine, can be embedded in the technology, and
can have much teaching delegated to it. Alternatively, to expand the
range of courses that can be taught at a distance, the use of technol-
ogy should be carefully designed so that expensive labor at least can
be replaced by cheaper help. For example, the Open University
makes liberal use of tutors (replacing many full professors), either in
person or on the phone.

Third, technology should substitute for labor as simply as possible.
As the example of the Open University suggests, most low-cost dis-
tance learning does not fundamentally change the learning experi-
ence for the student, or the teacher. A computer application that
promised to play a substantial role in teaching but that also de-
manded broad changes in faculty skills and activities (several of
which are discussed in Chapters Three and Four) could actually in-
crease labor costs, even while guaranteeing a savings in teacher time.

The bottom line, then, is that today’s distance-learning technology is
largely limited to imparting relatively routine skills and knowledge,
taught en masse, through relatively traditional methods. Most of the
best examples actually come from military and corporate training,
rather than from higher education. For example, large companies
such as Ford now contract for distance instruction to help their em-
ployees learn how to use tools such as spreadsheets and word pro-
cessors, as well as specialized equipment. And Hewlett-Packard es-
timates that it saves millions of dollars each year using distance
learning to train employees more effectively and more efficiently
than with conventional methods. These examples explain why well
over one-half of distance learning now goes on not in academic set-
tings but in businesses—a market that is expanding so rapidly that
whole TV networks are now dedicated to corporate distance learning.

The Internet is increasingly being viewed as a medium that can bring
distance learning and its cost benefits into the higher-education sec-
tor. In the next subsection, we look at the cost and other advantages
the Internet in particular can provide as a distance-learning tool for
higher-education institutions.
Internet Impact: Distance Learning, Cost Reduction, and Increased Access

At least partly to cut costs, almost all higher-education institutions in the United States are considering distance-learning programs, dozens already have substantial offerings in place, and many universities are now moving in this direction. In the future, we believe that the Internet will be the most cost-effective way to deliver a new generation of distance-learning courses. By winter 1996, the U.S. Distance Learning Association (http://www.usdla.org/home.html) listed many dozens of universities with homepages outlining their WWW and Internet-based courseware. At the same time, the World Lecture Hall, a Web site managed by the University of Texas, has become a “virtual repository,” organizing links to hundreds of other sites that are making Web-based class materials available to anyone who is interested. (See Chapter Three for a more complete description of the World Lecture Hall.)

Because the WWW first came online only in 1991, all these courses are new, and there are no solid data proving the effectiveness of Internet-based distance education. But a chemistry curriculum drawn almost at random from the World Lecture Hall illustrates some of the reasons why Web-based distance learning seems very promising, at least “on paper.” (See Figure 2.3.) To begin with, emerging Internet courses can include a wealth of material about the class (lectures, exams, assignments) and references to relevant online literature (books, programs, tools such as the periodic table), all accessible at the click of a mouse on a hypertext link. Each of these sources can be constructed as multimedia documents, including pictures, digitized audio versions of lectures, presentation overheads—even simulations, which can be run to give a much more dynamic impression of processes and structures. Full high-bandwidth interactivity will be available soon, to support multi-person, multimedia dialogues in real-time. The new generation of

2This curriculum was found under the “Chemistry” entries on the World Lecture Hall homepage (http://www.utexas.edu/world/lecture/index.html) on February 22, 1998. The course itself was at Brown University (http://jcbmac.chem.brown.edu/baird/Chem22I/chem22i.html) on the same date.
Chemistry 22C is taught by Prof. James C. Baird of Brown University. The WWW course materials, found indexed under “Chemistry” on the World Lecture Hall, include

- online lecture notes
- lecture “overheads”
- digitized audio of actual lectures, which can be played, rewound, replayed
- homework assignments and answers, updated weekly
- electronic archives of past final exams and answers
- pointers to online resource material.

Students access these different resources just as they do any Web homepage: by pointing and clicking on text links.

While this example is quite complete, it did not include features found in a few other course homepages:

- **Calendar of class sessions.** Often presented as a table, including date of the class and daily topic. The topic description is often hypertext; clicking on it allows access to the material for the class (lectures, overheads, etc.).

- **Virtual office hours.** Some professors included buttons that allowed students to send e-mail to them or to other students in the class.

- **“Chat” rooms.** In some classes, students can login and engage in text-based discussions with other students from the class who also happen to be on at the same time. Faculty also often pre-arrange virtual office hours: times at which they will be logged-on as well.

- **Video and movie clips.** Video clips (usually less than a minute in duration, given current time and space constraints) are sometimes included in Web courseware to demonstrate complex physical processes, for example.

- **“Live” computer programs.** In an increasing number of Web-based courses, students can run simulations, in addition to viewing static lecture materials. The simulations run on remote machines, but display on the user’s machine, and often permit the student to interact with the simulation and control its execution—for instance, using forms to input simulation parameters.

---

Figure 2.3—Internet-Based Distance Learning: Today and Tomorrow
Internet-based distance-learning courses, in short, can mix the graphics and video of instructional TV with a much more intimate style of interactive mentoring than teleconferencing ever could. Therefore, it should provide substantially richer learning experiences for students than the current generation does.

Web-based distance learning might enhance productivity in higher education in several ways. Most obviously, by providing a more powerful and flexible medium, the Web should enable developers to construct higher-quality courseware for a wider range of classes than ever before. (See Figure 2.4, top panel.) With richer courseware, classes for which computers once replaced only a modest amount of labor might shortly be taught almost exclusively through technology; and in courses in which information technology previously had no part, it may play at least a supporting role. All this means that Web-based learning tools, appropriately used, promise to replace more labor and, consequently, to lower faculty costs.

But less-visible features of Internet-based distance learning—costs and standards—may enhance productivity even more dramatically. It is reasonable to assume that if courseware built on the Web is richer than previous distance-learning products, it might also be more costly to deliver—reasonable, but probably wrong. Although few realize it, the Internet is not only a better medium for learning and interaction but a cheaper way to deliver instruction (Figure 2.4, bottom panel)—something providers of corporate training have already figured out. For example, corporate providers are quickly trading their old on-demand video systems for more-flexible and less-expensive high-capacity intranets, which use Internet-style communication on private networks to deliver full-motion video to hundreds of viewers at once, at the click of a mouse. (See Figure 2.5.)

Schools and homes can expect similar benefits, even if they cannot afford the high-capacity LANs of big business. High-bandwidth yet low-cost connections to the WWW will soon come in several forms. Many homes today can access the Internet cheaply through ISDN phone connections, providing about 5 to 10 times the effective bandwidth of ordinary phone lines. More interestingly, successful trials of cable modems in 1996 promise very high-speed Internet connections, at roughly the cost of standard cable service. (See
The Internet’s promise for distance learning is based on its potential to provide a flexible and high-functionality medium for delivering instruction, at a cost that is now within reach and steadily dropping.

The powerful functionality is based on several features:

- **Two-way interactive communication.** The Internet supports distance learning, whereby students communicate with teachers (or technology), as easily as it enables learning where teachers communicate to students. Generally, students learn better from interactive courseware than from one-way instruction. Of course, if desired, TV-style distance-learning lectures can readily be simulated on the Internet.

- **On-demand communication protocol.** Courseware is accessed on the Internet whenever the user wants it, and from wherever the student plugs in his or her machine. No need to remember when an instructional show is on, or even to set the VCR.

- **Wide communication bandwidth.** Recent advances in compression, coupled with innovative ways to use existing infrastructure (new modems that transform TV cable into full-duplex computer connections, and ISDN as well as ADSL for copper phone wire) will make roughly the capacity of two-way video available to most Internet users.

Costs are dropping for several reasons:

- **Hardware needed for Internet access is dropping quickly in price.** In 1995 Web access required at least a low-end PC; less than two years later, “Internet appliances” such as WebTV (http://www.webtv.net) permit Web surfing at about the cost of a television plus monthly cable charges.

- **Network costs are dropping to zero.** Or, more precisely, the cost of using the Internet is low and independent of distance, so it should be just as cheap to access distance-learning material from New Zealand as from next door. (This is why more and more people are using the Internet for their telephone service, to the consternation of long-distance phone companies.)

- **De facto standards are making it easier to develop sharable courseware.** The WWW is rooted in a few document and communication protocols to which most homepage builders (or, more generally, publishers) currently adhere to. This may not make it easier to build any single distance-learning product, but, in the long run, it will help the community as a whole create better courseware.

Figure 2.4—Is the Internet the Medium of Choice for Distance Learning?
VIDEO ON THE INTERNET

In some ways, Web TV resembles on-demand video systems that some companies already use for training videos and inspirational messages from above. Indeed, it might even be better. One failing of corporate video systems has been the need for a user to download the video from an archival computer (known as a server), store it on the receiving computer (the client), and then “decompress” it before being able to play it back with special viewing software—a process taking anything from ten minutes to a few hours. With Web TV it should be possible simply to click and watch.


Figure 2.5—The Internet As a Higher-Functionality, Lower-Cost Way to Deliver Video-on-Demand

Figure 2.6.) If this promise is realized, the much-heralded-but-never-accomplished “500 channels of cable TV” finally could turn into something really useful. And, because they require no new and costly infrastructure development, wireless connections, such as

CABLE MODEM TRIAL DEEMED SUCCESSFUL

A marketing trial of high-speed cable modem service conducted by Time Warner subsidiary Paragon Cable has shown virtually no churn among its 200 test participants and the waiting list is still about 300 customers long. “There’s a real business here,” concludes Paragon’s general manager. Elmira, NY, cable customers paid a $30 installation charge and a $25 fee to receive Zenith modem units that provided access to a local database and to the Internet. Building on their success, Paragon plans to take the service commercial in Elmira at the end of March, and Time Warner is scouting out other likely locations for pilot programs. (Broadcasting & Cable, January 29, 1996, p. 48)

NOTE: Edupage can be accessed at http://www.educom.edu/. Select Publications, then select Edupage from the available links. Select the desired issue by its date.

Figure 2.6—Internet Access at the Cost of Cable TV Connection
DirectPC (http://www.helius.com/), may be the most promising of all. In short, the technical problems facing the installation of inexpensive wide-bandwidth Internet connections are all but solved; the policy barriers, however, loom large, as we discuss in Chapter Six.

In addition to reducing educational costs, the shrinking price of delivering Internet-based distance learning should help address other challenges for higher education. For one thing, Internet-based distance learning could be conveniently accessible to many different kinds of learners. Part of this improved access simply means putting more people in touch with more learning resources. A new wave of cheap “Internet appliances” (dumb terminals dedicated to Web browsing) should bring Internet access within almost anyone’s budget; anyone who can afford Nintendo should be able to afford the WWW.\(^3\) And once on the Internet, all resources are equally inexpensive to browse, whether they happen to be on a homepage next door or thousands of miles away. Equally important for improved access is the ability of Internet distance learning to reach consumers at any place and any time. This flexibility will be especially important, for example, to workers who want to “retool” skills at night while working during the day.

**Reflection: The Death of Distance As a Barrier to Learning**

At the broadest level, an Internet style of learning or instruction delivery will, we believe, be so common that it makes little sense to view distance learning as a special form of education delivery. Since Internet and Web tools will continue to drop in cost and increase in functionality for the foreseeable future, technology should, over time, displace more and more faculty labor. Further, what labor cannot be displaced will at least not have to be nearby: The Internet can connect students with faculty and peers as easily as it connects learners with multimedia documents. Eventually, then, most learn-

\(^3\)Although dropping technology costs will make the Web accessible to make many, it may be still beyond the means of many urban poor—a group who arguably might benefit most from access to low-cost educational services. As of 1993, only 7 percent of households in the bottom quartile in income owned a computer. Further, recurring Internet connection costs (still at least $20 per month in 1998) are substantial. See How Will Individual Learners Access Internet-based Education? below and, especially, Anderson, Bikson, et al. (1995) for further discussion of these access issues.
ing will be distance-independent, and the special cases will be those that are geographically bound.

Perhaps more to the point, distance learning should be viewed as a common tool in higher education, not as a separate—and esoteric—option. And most courses should be designed to use distance learning in some capacity, and often in a variety of capacities. A wide range of experiments in distance learning are already under way, and they come in many forms, rather than all fitting one mold. (See Figure 2.7.) The degree to which direct interactions are replaced can vary significantly: Telecommunications are sometimes little more than an add-on to classroom lectures; conversely, taped lectures may be the centerpiece of instruction, with face-to-face tutoring serving as a supplement; in still other cases, all discussion happens at a distance.

There is no single, obvious way to order courses from light to heavy users of distance-learning technology. Some courses that are, for example, offered exclusively at a distance (no face-to-face interaction) still make less use of telecommunication connections than classes that also include some direct contact. We ordered the following list roughly from courses that provide narrow connectivity, overall, to those that provide rich interactions. The list in Figure 2.7 is only illustrative; many distance-learning courses already mix and match features and functionality in ways we do not include here.

Less obviously, examples also differ in the bandwidth of communication, as well as the degree of interactivity. Early distance-learning courses (through postal mail) trafficked only in text, and a single interchange required days, if not weeks—not at all interactive by today’s standards. Videotaped lectures distributed from a centralized source offer much greater bandwidth but no more interactivity; on the other hand, e-mail discussions between teachers and students are highly interactive but narrow in bandwidth. Some of the newest Internet-based distance learning enjoys both broadband, multimedia connections and real-time interactions, often linking not only faculty with students, but students with one another and with shared online resources. While earlier distance-learning models delivered knowledge from a centralized teacher (or “server”) to students through narrow, slow, and separate connections, newer models look
<table>
<thead>
<tr>
<th><strong>Features and Functionality</strong></th>
<th><strong>Examples</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>low bandwidth, non-interactive technology; no face-to-face contact</td>
<td>Pittman’s correspondence courses on shorthand in the 1840s</td>
</tr>
<tr>
<td>high bandwidth, non-interactive technology; no face-to-face contact</td>
<td>The Teaching Company (see Figure 2.10) video and audio tapes, augmented by written course material</td>
</tr>
<tr>
<td>low- to mid-bandwidth, non-interactive technology; some face-to-face contact</td>
<td>early courses from the Open University (see Figure 2.2), mainly based on paper materials, and telephone and face-to-face tutoring</td>
</tr>
<tr>
<td>high-bandwidth, non-interactive technology; some face-to-face contact (tutoring supplements distance learning)</td>
<td>many corporate training courses using “Web TV” (see Figure 2.5) are centered on on-demand multimedia courseware, but also include on-site discussions</td>
</tr>
<tr>
<td>high-bandwidth, non-interactive technology; extensive face-to-face interaction (distance learning supplements traditional)</td>
<td>many satellite- and TV-based distance-learning courses, for which classes are planned around regularly scheduled broadcasts</td>
</tr>
<tr>
<td>high-bandwidth, interactive technology; some face-to-face contact (tutoring supplements distance learning)</td>
<td>some World Lecture Hall classes; courseware is put online as an adjunct</td>
</tr>
<tr>
<td>low-bandwidth, interactive technology; connectivity among students and distributed resources, as well as among teachers; no face-to-face contact</td>
<td>some asynchronous learning courses (see Figure 2.8); students near a campus may come to on-site tutorials</td>
</tr>
<tr>
<td>high-bandwidth, interactive technology; fully connected community (teachers, students, resources, and experts); no face-to-face contact (optional)</td>
<td>educational MUDs or MOOs (see Figure 2.9), where collections of learners (mentors and students) engage in text-based dialogues in real-time and construct textual “worlds”</td>
</tr>
<tr>
<td>high-bandwidth, interactive technology; fully connected community (teachers, students, resources, and experts); no face-to-face contact (optional)</td>
<td>newer Internet-based course from the Open University (<a href="http://www.open.ac.uk/">http://www.open.ac.uk/</a>), where face-to-face tutoring can be replaced by online tutoring and e-mail</td>
</tr>
<tr>
<td>high-bandwidth, interactive technology; fully connected community (teachers, students, resources, and experts); no face-to-face contact (optional)</td>
<td>many courses offered at virtual universities such as Athena (see Figure 4.4)</td>
</tr>
</tbody>
</table>

**Figure 2.7—Near and Far: The Many Forms of Distance Learning**

much more like an electronic community, tying together students, faculty, and distributed tools in a rich, speedy web of digital contacts.

With so many variants, it is no surprise that what makes an application of information technology an instance of distance learning is
becoming less and less clear. For example, courseware such as the chemistry curriculum in the World Lecture Hall might be used in a distance-learning class; but right now, it is simply online material for an on-campus course. However, merely by skipping lectures and labs and relying on the rich Web documents to compensate for reduced in-person contact, individual students may turn it into a virtual distance-learning course. Such individual experiments, which probably have gone on informally for decades, now are leading to large-scale studies that will try to gauge the importance of distance as a barrier to learning in technology-intensive courses. (See Figure 2.8.)

It is useful to view this increasing freedom from spatial location in terms of the progressive “unbundling” of teaching functions in higher education as educational technologies have changed across time. Centuries ago, when knowledge was conveyed exclusively through an oral tradition, location was everything. With the advent of written texts, students were freed from the need to attend lectures (logically, but not always legally); however, other important functions, including tutoring, counseling, and evaluation, remained essentially face-to-face activities.

Now, just as books (and cars) have weakened the links between distance and learning in the past, today new information technologies can almost break them. Since the Internet can connect students with

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The Alfred P. Sloan Foundation is funding research on asynchronous learning networks (ALN) as part of its Learning Outside the Classroom program (http://w3.scale.uiuc.edu/education/ALN.new.html). Courses are used by students at varying distances from campus—living on campus, within commuting distance, or very far away. Two of the questions being examined by different projects are

- How well do students learn as a function of distance from the physical classroom?
- How do students’ learning practices differ as a function of distance?

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Figure 2.8—Does Distance Matter in Asynchronous Learning Environments?
teachers as easily as it connects students with course material, tutoring and counseling can be (and are) done through e-mail and real-time chat rooms. (See Figure 2.4.) Similarly, as reference materials increasingly become available in digital form, students will no longer need proximity to libraries. Evaluation and assessment also can be done at a distance. Written products, such as essays, already are created routinely with word processors; sending them across a network for grading can be easier than printing them and walking them into a professor’s office. Multiple-choice as well as short-answer tests have been computerized for years. In a pinch, even timed, closed-book exams could be conducted using simple keystroke logging or more sophisticated Internet video products such as CU-SeeMe (http://cuseeme.cornell.edu/) for proctoring.

Again, the point is not that learning should be conducted at a distance, just that creative applications make distance less and less of a barrier to learning. The challenge will be to discover the most effective applications of distance-learning technology and to blend them together with traditional face-to-face transactions.

INCREASING QUALITY AND PRODUCTIVITY

While many applications of information technology in education try to reduce costs, others focus on the output side of the productivity equation: helping students learn more or better, or to learn new skills—applications rarely included in higher-education curricula. A collection of examples (Figure 2.9) illustrates several ways in which information-technology applications could lead to better learning and teaching outcomes.

CAI and CBT

As discussed, most successful computer-aided instruction and computer-based training applications boast of cost reductions (Figure 2.1), but a few also claim gains in the quality of student learning. Some of these applications rely on distinctly cutting-edge technology, making lavish use of multimedia, and engaging students in highly interactive discussions. However, other ideas are surprisingly simple. For example, The Teaching Company (TTC) thinks that the videotapes and audiotapes it offers can help college students
improve grades in everything from history to psychology to physics. Of course, these tapes lack the interactivity of a good tutoring session, but TTC is gambling that the quality of its tapes will more than compensate: The lectures are delivered by elite, “superstar” faculty in each field, not by merely competent professors.

Some very positive reviews of these products (Figure 2.10) may be too optimistic. However, in the future, Web technology could clearly

<table>
<thead>
<tr>
<th>System/Study</th>
<th>Quantitative/Qualitative Learning Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAI and CBT</strong></td>
<td></td>
</tr>
<tr>
<td>Fletcher (meta-analysis of 47 studies) (1989)</td>
<td>-.50 standard deviations improvement in achievement (IVD technology, averaged across higher education and military training)</td>
</tr>
<tr>
<td>Kulik (review of many studies and 12 meta-analyses) (1994)</td>
<td>-overall small increases in learning, across academic, adult learning, and training settings (CBT technology)</td>
</tr>
<tr>
<td><strong>Intelligent Tutoring Systems</strong></td>
<td></td>
</tr>
<tr>
<td>SHERLOCK (Katz et al., 1993)</td>
<td>-provides the equivalent of 4 years of on-the-job training in electronic troubleshooting in 20 to 30 hours</td>
</tr>
<tr>
<td>ACT tutors (Anderson, Corbett, et al., 1995)</td>
<td>-30 to 60 percent faster learning of programming skills, 30 to 40 percent higher scores on tests -one-grade (e.g., C to B) improvement in geometry</td>
</tr>
</tbody>
</table>

Figure 2.9—Information Technology and Quality Learning (continued on next page)
### Interactive Learning Environments

| **Apple’s Classrooms of Tomorrow (ACOT) schools (Dwyer, 1994)** | - studies show students wrote better, completed units in math more rapidly  
- by the end of 4 years, students changed how they did work, freely employing inquiry, collaboration, and general problem-solving skills |
| **Collaborative visualization (CoVis) project (Gomez and Gordin, 1996)** | - young students were able to acquire sophisticated understanding of climate and global warming  
- they were also able to use high-tech visualization tools, engage in open-ended inquiries, and learn collaboratively |
| **Massively parallel microworlds (Resnick, 1994)** | - young students were able to learn about complex distributed systems using simulation models run on parallel machines  
- they were also able to learn general heuristics for modeling decentralized systems |
| **MUDs, MOOs, and MUSEs** | - most results are anecdotal, but broadly, MUDs may help learning of:  
- academic skills (programming, reading, typing, writing)  
- metacognitive and generic skills (scientific method, learning to learn, help seeking)  
- personal and social skills (motivation, collaboration, trust) |

Figure 2.9—(continued)

make educational packages featuring superstar instructors easier to develop and more broadly accessible, perhaps leading to significant improvements in teaching and learning productivity. Imagine, for example, a course built around master lectures, digitized and put online, and combined with complementary assignments, projects, tutorials, and group discussions—like those already found in World Lecture Hall courses. Taking this course through the Internet might not be quite the same as being there in person, which would require being a student at MIT, Stanford, or a similarly elite and pricey institution. Nonetheless, for less-fortunate students, such an online
The Teaching Company is a for-profit business that offers more than 60 audio and video courses on a wide range of academic subjects, from science to philosophy. Most are at the college level. Their main selling point is that lectures (the courses are in very traditional delivery formats, with little support material) are taught by a “dream team” of “superstar” teachers. Almost all have first-rank U.S. university affiliations. While The Teaching Company offers no solid evidence of student learning (in fact, they provide no tests or accreditation), they do pepper their brochures with testimonials from the likes of Ted Kennedy, Orin Hatch, and the Los Angeles Times.

Figure 2.10—Online Superstar Teachers: Goodbye to the Merely Good?

course could be better than an in-person course offered by a second-tier university. Here, as in other areas, information technology might lead to improvements in productivity by making truly great—not merely competent—practitioners and their performances available to almost everyone.4

Intelligent Tutoring Systems

While replicating outstanding teaching performances on video might lead to improvements in learning productivity, a much more ambitious approach is to try to capture, in software, the reasoning of teachers. Of course, this cannot be done just by pointing a camera at a smart talking head. Rather, the process of developing so-called intelligent tutoring systems (ITS) begins with an expert system—a collection of heuristic rules—that is capable of answering questions and solving problems in a given subject matter. For instance, the expert system inside a good calculus ITS would be able to solve arbitrary symbolic integration problems, and would do so in a way that ap-

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4See, for example, Rosen (1981) for an economic analysis of how information technology makes great performances widely available, increases the wealth of the elite (at the expense of the merely gifted), and therefore shrinks the number of people who can make a living providing information services to a small contingent. Rosen claims that this phenomenon applies not only to entertainers and sports figures, but (to a lesser extent) to lawyers and business executives, whose range of influence and availability is expanded by modern telecommunications.
proximates how an “ideal” human mathematician would reason. The expert system in an ITS is often supplemented with a student-modeling capability, which can examine a student’s reasoning, find the exact step at which he or she went astray, try to diagnose the reasons for the error, and even suggest ways of overcoming the impasse.

The potential value of such highly intelligent systems is obvious. Indeed, for decades, the idea of supplying students with their own automated tutor, capable of tailoring learning experiences to students’ needs at a fine level, has been the holy grail of teaching technology— with good reason. Many studies have shown that one-on-one tutoring is the best way to learn. And, as the examples in Figure 2.9 demonstrate, for a few academic subjects, ITS have nearly matched the capabilities of their human-tutor counterparts, helping to raise students’ scores one letter grade or more.

However, while such systems show that ITS can raise the output side of the productivity equation in education, their successes to date are very limited. Because they try to embed detailed human-reasoning skills, both in subject-matter areas and in teaching expertise, they rely on advances in cognitive theory and software engineering. But these disciplines have yielded a detailed understanding of thinking in only a very few well-defined subjects; consequently, ITS currently are confined to relatively simple parts of algebra, geometry, computer programming, physics, and other sciences.

In higher education, then, ITS probably would be most appropriate in basic freshman and remedial classes. And, needless to say, even in these subjects, automated tutors come nowhere near the ability to mimic superstar teachers. On the contrary, ITS are frequently called “brain damaged” by most computer scientists, their developers included. Over time, however, ITS will get smarter and smarter. Buttressed by advances in cognitive science, they will capture an increasing share of human-teaching expertise, and they will extend to a wider range of subjects.

However, all evidence suggests progress here will be slow. While the speed of computer hardware continues roughly to double every two years, the intelligence of computer software, however you measure
it, creeps ahead at a snail’s pace. But this does not mean that information technology is destined to play only a minor role in helping improve the quantity and quality of learning in higher education. It just means that some of the most obvious ways in which technology attempts to partially replace faculty as lecturers or tutors in a traditional classroom setting may not be the most promising ways, at least in the short run.

Interactive Learning Environments

A glance back at Figure 2.9 suggests that some of the most successful applications of information technology follow a very different principle: Instead of mimicking human tutors, they provide rich, simulated environments that enable students or trainees to practice skills intensively. Flight simulators, the first such learning environments, are still perhaps the most compelling ones. For decades they have been singularly effective technologies for improving the quality of pilot training. In the protective environment of a virtual cockpit, pilots can perfect difficult maneuvers, trying them over and over without fear of the deadly effects of a real-world mistake.

SHERLOCK (Figure 2.9), a descendent in spirit of these early simulators, demonstrates similarly impressive outcomes: Students can learn electronics troubleshooting and fault-diagnosis skills in less than one-tenth the time they previously required. While SHERLOCK includes some important coaching supports, the basic reason that trainees acquire skills so rapidly is simply that the system can present students with simulated problem situations that arise only rarely in the real world—namely, troubleshooting the complex hardware that diagnoses faulty F-15 avionics.

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5Well-publicized successes of “man over machine,” such as Deep Blue’s recent win over world chess champion Gary Kasparov, are false counter-examples. Deep Blue’s performance relied almost exclusively on fast computer hardware. The program uses brute-force searches and “understands” virtually nothing about the way humans play the game. It is just this kind of understanding that automated tutors must possess if they are to help humans learn.

6Interactive and simulation-based learning environments such as those we discuss here are certainly not the only alternatives to ITS and systems that try to be “smart” or human-like. A few, listed in Figure 2.9, take different approaches; for example, some offer new “power tools” for collaborative learning.
Trainees do not learn these troubleshooting skills very quickly in the field, because problems that might foster new knowledge naturally occur, say, once every few weeks. Using SHERLOCK, such problems can be made to order every few minutes, if necessary. More generally, this and other virtual worlds rely on the fact that one of the most powerful ways to learn is by doing; but learning-by-doing works well only if the world cooperates by providing the learner with a large number of practice cases, and cases suitable to the learner’s current level of expertise. In situations where the real world cannot be easily controlled or does not readily cooperate, computers can now provide rich simulated worlds, at an arbitrarily high degree of fidelity, that can be controlled with the click of a mouse.

Such environments seem promising tools for training, but can they work in higher education? While it is relatively easy to imagine how simulated worlds might be useful in teaching concrete subjects such as electronics or even physics, it is less obvious how simulations would help in abstract or symbolic disciplines such as history, philosophy, or the social sciences. However, some innovative systems are already pointing the way. For example, CoVis (Figure 2.9), Rebel! (Figure 2.11), and even strategy games such as SimCity, are built on top of complex computational models that capture key features of the real-world dynamic systems underlying policy decisionmaking, weather, and historical processes. True, these models do not simulate concrete physical systems; but, at an abstract level, the conceptual systems they represent also comprise dynamic cause-and-effect relationships among a collection of variables. What a new generation of simulation-based learning environments are doing, in essence, is combining computational models of such processes with highly graphical and easy-to-manipulate “visualization” front-ends. Collectively, these environments give the learner a virtual world in which many what-if experiments can be performed.

In theory, then, just as SHERLOCK provides trainees with a large number of rich avionics cases, these simulations might present learners with, say, a series of hypothetical history scenarios, some of which may have analogs in real historical events and some not. These technologies appear very interesting, but they are also very new. Whether they can lead to the dramatic gains in the quantity of learning we find with SHERLOCK remains to be seen.
Rebel! is an interactive, exploratory simulation environment for learning history—in particular the American Revolution—by playing what-if games (e.g., “What if the British had sent over more troops?”). Using it as a stand-alone system, students start the simulation, then set certain parameters (to operationalize their questions), either by loading scenarios that define collections of values or by changing them individually. Next, the system runs, and, as simulation time steps forward, the student views the virtual world unfold in a series of graphical depictions of simulation state changes. At any point the student can interrupt the run and click interface buttons that help give a better understanding of cause and effect: what was happening, and why.

We transformed Rebel! from an isolated simulation (running and displaying on the same machine) into a distributed one (running on a remote machine, and displaying on a local one) using the following procedure:

1. The initial homepage shows, on the local interface, a picture of the initial Rebel! interface (saved as a GIF file, referenced in the HTML code for the page).
2. The initial page also includes a Begin button, which, when clicked, triggers a script that causes Rebel! to begin running on the remote machine; it also invokes a new HTML page—the initialization page.
3. The initialization page allows the user to select from pre-existing scenarios and to set values for specific parameters. When the form is complete, the user clicks the Run button. This invokes a script that ships all the initialization data back to the remote machine, where the Rebel! process is waiting for it. On the remote machine, the simulation parameter values set by the user on the local machine are then read in, and the remote Rebel! simulation run actually starts.
4. As the simulation runs, it periodically updates its state and writes (actually, creates on the fly) a new HTML document (representing the simulation state), and puts it into the output file, to be displayed on the student’s local machine.
5. HTTP protocol on the local machine polls the remote machine at regular intervals, looking for an updated interface document in the output file, and loads it when necessary.
6. “Stop” is always one option on each reloaded document. If the student selects the Stop button, a script writes instructions to a user input file on the remote machine, which causes the remote simulation to suspend.
7. Throughout the run, a similar protocol enables the user on the local machine to interact with the simulation on the remote one: the simulation always looks for messages in the user input file to modulate its behavior, and the Web browser on the local machine always updates its image of the simulation interface by reloading the simulation output file.

Figure 2.11—Transforming Rebel! from an Isolated Application to a Web Distance-Learning Tool
Internet Impact: Turning Expensive Stand-Alone Systems into Cheaper Distance-Learning Technologies

Some of the applications that promise to help raise educational productivity by improving student learning, rather than by cutting costs, are already network-based systems. In CoVis, for example, students use the Internet to communicate with distant mentors, collaborate on projects with peers, gather data from remote sites, and talk with experts in atmospheric and environmental sciences. (See also Figure 2.12.) But many of the cutting-edge applications are stand-alone systems that run on only one or a few computer platforms. For instance, one might work on a Macintosh but not on a PC. Even worse, since many of these systems are still research prototypes, they may run on only relatively high-end machines (Sun Workstations or even supercomputers, for example). All this would seem to mean that some of the most interesting new information technologies for higher education will be, for the foreseeable future, either inaccessible to most students or prohibitively expensive for schools or students to acquire.

Not necessarily. One way around this problem, again, exploits the Internet and the WWW. It is already possible for stand-alone software systems to piggyback on the near-standard protocols for creating WWW documents. In doing so, these systems can be made available very widely and relatively cheaply.

As anyone who uses the WWW knows, Web browsers and servers, unlike most software, run on a wide range of machines. The considerable complexities of making key languages (such as HTML) and protocols (such as HTTP) de facto standards are hidden from the average user, who can happily create documents that will appear on any machine just about the same as they look on his or hers.\(^7\)

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\(^7\)The universality of Web standards such as HTML and HTTP is more fragile than it might appear. Even the simple current versions of these protocols do not run on all machines. Future versions threaten to be even less general. For one thing, different groups are extending the basic standards in many incompatible directions; for another, the pressure to develop highly interactive Web objects quickly is speeding up the pace of innovation, which works against the slow processes of achieving a broad-consensus standard. That said, the current HTML and HTTP standards are far closer to a universal standard for complex computational objects than anything we have seen before.
Technically, only WWW documents enjoy this relative machine independence. However, using scripting languages (e.g., CGI) that enable programs to be initiated on remote machines and new homepages to be created and loaded on the fly, it is possible to turn almost any piece of educational software into a distance-learning application.8

The cleverness needed to turn isolated software into sharable distance-learning systems on the WWW might be of technical interest to some readers. (Certainly the exercise has fascinated the authors.) But such technical subtleties miss the key point of the example: Already, the Internet and WWW permit high-powered applications that run only on high-powered machines to be accessed by students who might have available only low-end machines—and almost any kind of low-end machine, not just those that the original application developer envisioned.

The future looks even more promising, on several scores. First, as already noted, ultra-cheap Internet appliances should bring down access cost even further. Second, the protocols needed to make products widely sharable across the Internet, using almost any hardware platform, are quickly falling into place. Tricks now required to turn the WWW into an interactive medium will soon lose their appeal, primarily because new Web tools, and languages such as Java, for building “live computational objects” (it is misleading to call them “documents” any longer), will soon provide primitives that make this kind of interactivity easy to achieve rather than a challenging problem to solve.

All this may mean that higher education can have its cake and eat it too. Most of the current cutting-edge information-technology applications we reviewed promise to help students learn better or faster, or both. Improving educational productivity in this sense is clearly an important goal for higher education. But, until recently, this goal seemed at odds with others: reducing the cost of delivering education and increasing access to education by an increasingly diverse population of students. Without question, in the future, most appli-

8See Figure 2.11 for an example of how we turned Rebel! into a Web-based history simulation that could be run on one (high-end) machine but displayed on a variety of other (low-end) ones.
cations of technology in education that offer exciting possibilities for transforming teaching and learning will continue to be developed in corporate and university research settings on high-end machines. And these will probably remain expensive, well beyond the means of almost all students and even most higher-education departments and computer labs. However, high-bandwidth networks, coupled with increasingly standardized software languages and communication protocols, and with ever-cheaper Internet terminals, should bring these cutting-edge applications within reach of learners and teachers who do not have access to the newest and fastest technologies.

This does not mean that poor students will enjoy all the same access to technology-based learning as wealthy ones, of course. There will always be computers that offer more functionality at a higher price. And even if high-quality educational materials could be accessed by anyone on any machine at any time, nothing right now prevents providers from metering this access and charging whatever the market will bear. (Nor, necessarily, should providers be prevented. These and related policy issues will be examined in Chapter Six.) The point, however, is that information technology by itself will no longer be a significant barrier to access; if anything, the WWW and Internet should be a force toward greater access to and equity in education.

**Reflection: Many Interesting Options, Many Hard Choices**

Certainly information technologies do more than provide better tools with which to deliver instruction and learning materials in higher education, but such tools still dominate the field of educational technology. We have discussed (or at least pointed to) a wide range of these applications, focusing especially on those that exploit the WWW, or could do so. Stepping back from the many specifics, several general points should be emphasized.

First, it should be obvious that information technologies offer many different ways to improve instruction delivery, not just one. Looking just at distance learning, there is a rich set of options to choose from. Selecting from the different choices demands attention to the (often implicit) educational goals the technologies address. Some might help higher-education institutions reduce costs; others look better-suited to increasing access to educational resources, or to increasing
the quantity, quality, or speed of student learning. Overall, the prolifera
tion of Internet and WWW resources should steadily bring down the
cost of all educational software products and services. Yet, some
will be more costly than others, and a few will still be very expensive
for the foreseeable future.

In general, then, it is a mistake to assume that information technol-
ogy provides one or a few ways to improve learning and teaching,
and it is equally wrong to believe that technology applications will
affect just a single educational goal: cost reduction.

A third assumption, probably more widely believed, is also wrong:
that information technology is mainly a vehicle to enhance educa-
tional productivity. Look back for a moment at the last few informa-
tion-technology applications described in Figure 2.9. While some,
such as SHERLOCK, clearly intend to help speed up learning, or to
improve learning of well-defined subject areas, it is much less obvi-
ous how others are trying to improve educational productivity in any
simple sense. Instead, they are generally trying to transform the pro-
cesses and products of learning. For example, they might exploit new
visualization technologies to enable junior students to learn about
complex systems that previously only graduate students found com-
prehensible; and they might foster deeper understanding through
inquiry-based learning rather than traditional lectures, or through
collaborative-learning methods that simply never existed prior to
high-bandwidth networks.

In short, here information technology is a driver of educational
reform, not of productivity enhancement—unless productivity is re-
defined to include a wide range of qualitative changes, not just
quantitative improvements.

That these applications transform processes and products of learning
more than they enhance productivity has several implications for
their adoption, implementation, and costs. Consider, from the point
of view of the developer, how many different facets of an educational
context might need to change for the potentially impressive benefits
of such applications to be realized. (See Figure 2.12.) Clearly, the
technology itself—the tools actually used by students in learning—is
just the tip of the iceberg. Other possible changes range from the
roles of teachers, to methods of evaluating learning, to deeper philo-
sophical views of how learning happens and what constitutes know-
edge.

Here is what the CoVis researchers say about their project and goals (http://www.covis.nwu.edu/info/CoVis_OV.html):

“Traditionally, K-12 science education has consisted of the teaching of well-established facts. This approach bears little or no resemblance to the question-centered, collaborative practice of real scientists. Through the use of advanced technologies, the CoVis Project is attempting to transform science learning to better resemble the authentic practice of science. . . .

The CoVis Project will explore issues of scaling, diversity, and sustainability as they relate to the use of networking technologies to enable high school students to work in collaboration with remote students, teachers, and scientists. An important outcome of this work will be the construction of distributed electronic communities dedicated to science learning.

Participating students study atmospheric and environmental sciences through inquiry-based activities. Using state of the art scientific visualization software, specially modified to be appropriate to a learning environment, students have access to the same research tools and data sets used by leading-edge scientists in the field.

The CoVis Project provides students with a range of collaboration and communication tools. These include: desktop video teleconferencing; shared software environments for remote, real-time collaboration; access to the resources of the Internet; a multimedia scientist’s "notebook"; and scientific visualization software. In addition to deploying new technology, we work closely with teachers at participating schools to develop new curricula and new pedagogical approaches that take advantage of project-enhanced science learning. “Collaborative Visualization” thus refers to development of scientific understanding which is mediated by scientific visualization tools in a collaborative context. The CoVis Project seeks to understand how science education could take broad advantage of these capabilities, providing motivating experiences for students and teachers with contemporary science tools and topics.”

Figure 2.12—What It Might Take to Make CoVis Work
(continued on next page)
Here are a few of the transformations in traditional classroom practice needed to realize these goals:

- **Philosophy of learning and teaching.** Learning is no longer viewed as absorbing information but constructing meaning (instructionism vs. constructionism); inquiry rather than drill-and-practice is the preferred means of acquiring knowledge; and visualization as well as text-based comprehension is a key approach to understanding.

- **Teachers’ roles (and training).** Teachers act as mentors and guides to information resources, rather than as lecturers and sole sources of knowledge; they also must be fluent with new collaboration and visualization technologies.

- **Students’ tasks.** Students learn mainly through inquiry structured by projects; most projects are done in collaboration with other students and external experts (through network connections), rather than individually.

- **Curriculum structure.** Curricula are organized around authentic projects that embed long-term tasks comparable to those tackled by professionals in the field; small-scale tasks, such as solving a collection of algebra questions, are largely abandoned.

- **Classroom organization.** Classes are organized conceptually and physically by projects and computer networks. As students conduct their inquiries, the networks connect students and their tasks to external databases and experts who are sources of information, support, and commentary. Students spend little time engaged in paperwork at desks.

- **Evaluation strategies.** Authentic evaluation strategies replace traditional ones; students are evaluated on the basis of the quality of their projects, rather than their scores on short-answer or multiple-choice tests.

Figure 2.12—(continued)

All of this is roughly consistent with a simple rule we have distilled from our own research in developing and implementing educational technology: If a technology fits into an existing educational process and tries to enhance existing educational products, you spend 75 percent of your time developing the technology and 25 percent worrying about all other implementation issues; if a technology tries to transform educational processes and products, you spend 75 percent
of your time attending to these nontechnical, often complex, and frequently invisible changes in institutional practice and structure.

If anything, our 75/25 rule understates some of the complexities and costs of integrating cutting-edge applications into the classroom. True, it does suggest that deep institutional changes might be necessary to make the best use of some information technologies. However, it also seems to imply that we can anticipate the best ways to use these tools in advance, and that the biggest challenge will be to change the educational system to reflect what society knows it needs to learn and teach.

Although this statement is probably far too optimistic, who would have imagined a decade ago that visualization technologies or simulated worlds would open new educational experiences to learners? By the same token, it is extremely difficult to predict with any confidence what new and interesting applications of information technology for learning will surface over the next decade, or to imagine the kinds of institutional changes that might be necessary to best exploit these new tools.

This is not to argue that all good applications of the Internet and WWW to deliver education are shrouded in mystery. Again, there will be many options to choose from. Some applications—perhaps simple Internet distance-learning tools and the next generation of ITS—may continue to fit well into existing higher-education structures and to reduce costs or increase teacher productivity, others may give rise to new structures and cause us to rethink our ideas of educational productivity, and a few may transform learning in completely unexpected ways. Shortly, we will see additional examples of unexpected applications of information technology. Chapter Six follows up a few policy implications of this uncertainty.