Chapter 7

Training Technology

CONTENTS

Page

Boxes

Figures

Tables

Chapter 7
Training Technology

SUMMARY

Training technology includes a wide range of systems for delivering work-related instruction. Typically, the training system substitutes for real equipment or situations, or for worker memory. In its broadest sense, training technology encompasses both hardware (e.g., television sets, satellite dishes, computers, overhead projectors) and software (such as computer programs, television programming, written materials, and their instructional design), as well as the setting in which training takes place (for example, a classroom, the shop floor). The quality of training depends on the appropriateness and quality of the hardware and software as well as the ability of the instructor.

Training technology spans the low- to high-tech spectrum, from lecture/lab instruction or job aids such as checklists, to elaborate simulators and advanced electronic classrooms with interactive teleconferencing. Technology-based training might be delivered at a worker's desk or on the shop floor, at a training center, in a classroom, or even at an employee's home. The training may be undertaken individually, or in small or large groups. The courseware might cover all aspects of a job, or impart only those steps a worker needs to perform a particular task, or provide an update on technical or policy changes. The courseware can involve basic skills (e.g., literacy and arithmetic-see ch. 6); technical skills, such as equipment operation, maintenance, or repair; or interpersonal skills, such as sales or job orientation.

The principal findings of this chapter are:

- Technology-based training incorporating sound instructional design is cost-effective in helping American workers learn to use new equipment and production methods and prepare for changing work environments. The training duration, degree of learning achieved, and employee satisfaction with instructional technology often equal or exceed traditional classroom lectures. Because technology-based training typically is faster and more convenient to deliver than classroom instruction, it saves travel expenses and time off work.
- The costs of technology-based training are coming down. The hardware and software have largely matured and are affordable to most large and medium-sized firms. Indeed, where workstations already incorporate computers, using them to deliver training is extremely cost-effective. Costs are still an issue, however—especially for smaller firms.
- Innovations that promise to reduce costs further include: software that substantially reduces time and labor costs for instructional design and development, equipment and courseware leasing options, and learning centers.
- Corporate adoption of technology-based training is accelerating. Large companies such as IBM, Ford, and Motorola expect that by the late 1990s over half of their corporate training and education will be delivered outside the traditional classroom using instructional technology.
- Several factors inhibit broader use of technology-based training today. Incorporating technology in courses requires significant development and preparation, and often additional capital investment. Many corporate training personnel have had little exposure to instructional technology and lack enough hands-on experience to use it confidently or design courses around it. Also, early experience with poor courses has soured many firms on this approach.
- Several developments promise to stimulate more widespread use of training technology and enhance its capabilities. These include: the increasing power and declining cost of personal computers and other workstations and their software, including networked systems that facilitate development of electronic classrooms; the ability to embed training in production and other technological systems, bringing it to the workstation; and advances in broadband digital networks that will allow information of any type-text, graphics, audio, video, software-to be transmitted anywhere affordable.
- To facilitate spread of these developments in the long term, training professionals (instructors and managers) will need to become more sophisticated about instructional technology. Senior management and human resource devel-

opment departments must place a high emphasis on training technology. Corporations and the Federal Government will have to increase their research and development funding for instructional technology design and for adult learning.

TECHNOLOGIES

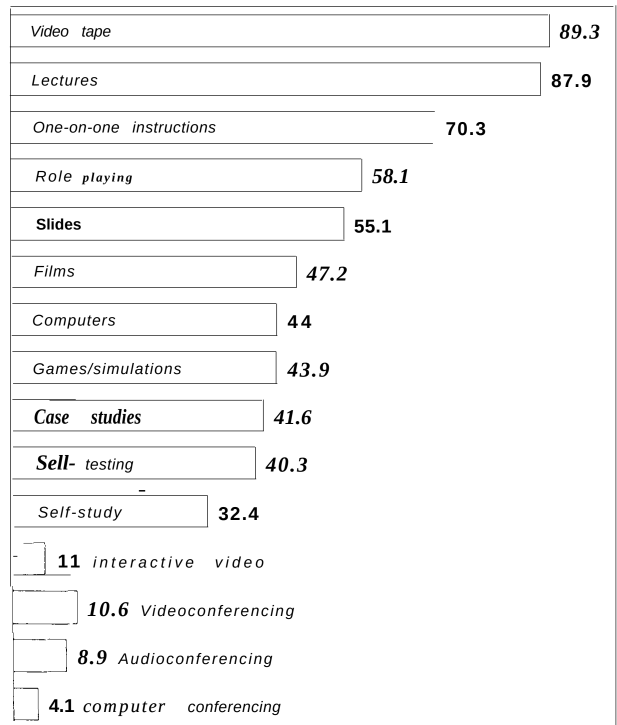
Instructional technology is not just hardware. The supporting courseware and delivery setting also are part of the technology. Box 7-A gives brief descriptions of the training technologies in use today; table 7-1 summarizes their characteristics, costs, and potential advantages and disadvantages. The appropriate type of instructional technology to be used is determined by the training functions and goals identified during instructional design (see figure 7-1).

Regardless of its form or delivery setting, instructional technology is an increasingly important part of the work environment. Workers must adapt to new equipment, new production methods, and changing work environments (e.g, teamwork, just-in-time production methods, computer-assisted manufacturing, paperless workstations). Training departments must respond quickly with cost-effective ways for employees to adjust. Today, many training professionals look to uses for technology-based instruction in their efforts to reduce training time and increase achievement in test results or job performance (see discussion of effectiveness, below). Technology-based training also is available at the worksite and provides consistent quality and delivery.

Technology has the capacity to provide environments that can promote learning and work simultaneously if designed carefully. Computers, for example, provide an ideal environment for unstructured learning. They both give and respond to commands and empower users to monitor and assess their progress. Good videodisc and computer courseware increasingly include interactive components (see box 1-C in ch. 1) that involve several senses and provide practice, repetition, and feedback-all of which aid learning. These approaches are now also being adopted in vocational training through, for example, workstations with sensors and pneumatic or mechanized components to teach electronics, programming, robotics, and computer-aided design.

Figure 7-l—The Use of Instructional Methods, 1989

Percent of companies with 100+ employees'



NOTE: This figure is based on data from a survey with a very low response rate. Hence, care should be taken in interpreting the results.

SOURCE: "Industry Report," *Training,* vol. 26, No. 10, October 1969, pp. 31-39.

Instructional technology may help hurdle the barriers between formal and informal learning. Successful training often occurs in practical and collaborative settings, such as apprenticeship, where the concepts learned are applied to daily tasks. Taking people away from the setting in which they are expected to use what they learn and putting them into classrooms risks teaching classroom practices only. Learning may have to begin again when trainees return to the worksite. Job aids and embedded training can contribute to on-the-job informal training—the kind most American workers receive.

Despite the potential advantages of technology-based training, lecture/lab instruction is still pervasive in the United States (box 7-B). Even training professionals usually learn about new training technologies in a traditional classroom setting. Yet, in terms of labor costs (and often travel), classroom instruction often is the most expensive form of formal training to deliver. Despite the higher initial development and hardware costs of technology-based training, it can be cheaper in the long run if

Box 7-A-Overview of Training Technologies

Television: The best-known and most widely-used technology-based instruction delivery system. The images, which are captured electronically, can be transmitted directly or stored on a medium such as videotape or disc. Telephone hook-ups can provide two-way audio capability for learner-instructor interaction. Transmission can be from microwave towers, through cable, or via satellite.

Videotape: A means of recording live or broadcast instruction. Video cassette recorders are inexpensive and highly reliable. Instructors can record programming to supplement their lesson plans; students can record classes, allowing them to "attend" whenever it is convenient. Students also can replay sections they did not understand the first time. A wide selection of commercially available programs cover most areas of training.

Analog Videodisc: Lasers store and read information—video, still pictures, text, computer graphics, audio-on discs. Video flames on a disc are made up from 525 horizontal scan lines with red, green, and blue components on each line. There are 54,000 frames per disc side. Videodisc currently uses a 12-inch plastic disc, but is moving toward smaller systems (8-inch dual-sided and compact disc) and digital technology.

Computer-Based Training: Computers can be the subject of instruction, as in courses on computer literacy, programming, or particular software packages; they can be used as tools for accomplishing other learning tasks, e.g., as word processors in writing courses or as design tools in graphics; they can be used to deliver instruction either prior to application (computer-assisted instruction) or at the time and place of application (embedded training); and they can be used to keep track of instruction (computer-managed instruction).

Teleconferencing: Teleconferencing, including audio, video, and computer conferencing, offers an increasing capacity to provide two-way (or more) communications. Teleconferencing can involve three technologies: telephones, television, and computers. Audioconferencing involves interaction among a number of participants via telephone bridges. Videoconferencing uses either full-motion or slow-scan television for interaction. Computer conferencing primarily uses electronic message systems (e.g., voice or electronic mail, bulletin boards) via local area or wide area networks or modems.

Simuliztors: Devices that duplicate the behavior of real-life machines (like ships or airplanes) or complex systems (like subways and powerplants). They typically contain a computerized model of the real equipment, and, depending on their level of sophistication, may duplicate all of the hardware and operating characteristics of the equipment and its operational environment. The instructor or a computer-managed instruction system presents operational situations (e.g., negotiating difficult terrain, specific malfunctions) to which the trainee responds.

Job Aids: Devices for helping a person remember or learn how to do a task when that task is to be performed (e.g., checklists, templates). Job aids (as well as embedded training and performance support systems) are designed to reduce the reliance on recalled skills and knowledge; they ensure effective performance on jobs in which specific skills are used infrequently or when a series of tasks must be performed in a particular order.

Performance Support Systems: A computer-based advanced form of job aid. A performance support system might incorporate any combination of text, graphics, audio, still video, applications software to perform specific job tasks, databases, expert systems, interactive training programs, assessment systems, and feedback and monitoring systems.

Embedded Training: Embedded training is instruction that is an integral component of a product or system. Because microchips are incorporated into so many workplace devices, it is possible to embed training in the devices themselves. This is a form of computer-assisted instruction, but instead of providing training in anticipation of need, it is offered at the point of application.

SOURCE: Office of Technology Assessment, 1990.

there is a large enough trainee population over which to spread the costs, or if the hardware and/or software already are in place (e.g., computer-based training, embedded training). Moreover, some workers are uncomfortable in classroom situations, relating them to bad school experiences or associating them with remediation.

There are several reasons why so much training uses little technology.[1] First, print materials and overhead transparencies are convenient to use.

[1] Greg Kearsley, "Instructional Technology and Worker Learning Needs," report prepared for the Office of Technology Assessment under contract No. L3-5615, February 1990.

Table 7-l-Characteristics of Training Technologies

Medium	Extent of Use[a] (percent)	Delivery settings	Degree of interactivity possible[b]	Estimated development time	Estimated delivery cost[c]	Potential advantaged	Potential disadvantages[d]
Lecture/lab	88	Group/ classroom	Potentially very high but depends on skill of instructor	1-30 hrs/hr	Usually very high, including trainee time off work; hardware is minimal	Familiar; provides social interaction; adaptable to any subject	Scheduling is difficult; often boring because trainee interest and involvement are so dependent on instructors skill; poor transfer of training to work
Television	90	Group/ classroom or individual	No branching; little feedback; little self-direction	80-240 hrs/hr	Low trainee time off; hardware is $1,000-$10,000 depending on equipment and type of programming	Familiar, available at numerous sites including home	Scheduling is hard without VCR; often boring; poor transfer of training to work; low interactivity; difficult to customize
Videotape	89	Group/ classroom or individual	No branching; little feedback; little self-direction	80-240 hrs/hr	Low trainee time off; hardware is $1,000--$5,000; coursewareis$100-$1 ,000	Familiar; available at numerous sites including home; can be viewed at any time; courseware readily available	Little interactivity; difficult to customize, often boring
Videodisc	21	Group/ classroom or individual	Varies; extensive branching, feedback, self-direction possible	40-1,000 hrs/hr	Low trainee time off; hardware is $400-$10,000; courseware is $70-$12,000	High interactivity; eventually will be available at numerous sites including home and the work station; excellent transfer to work; adaptable to most subjects; wide content variety; can be used at any time	Hardware usually dedicated to training; high cost for high level of interactivity; existing courseware difficult to modify
Computer-based	44	Group/ classroom or individual	Varies; extensive branching, feedback, self-direction possible	8-300 hrs/hr	Low trainee time off; hardware is $1,000-$l0,000; courseware is $50-$10,000	High interactivity; available at numerous sites including home and the work station; excellent transfer to work; adaptable to most subjects; wide content variety; courseware is easy to modify; can be used at any time	if hardware has to be dedicated to training then cost is high; some trainees are intimidated by computers
Videocon-ferencing	11	Group/ classroom or individual	Dependent on group; little self-direction	1-40 hrs/hr	Low trainee time off; hardware is $2,000-$10,000 per site	Social interaction; provides feedback	Complex logistics; high rest; adaptable primarily to soft skills
Audiocon-ferencing	9	Group/ classroom or individual	Dependent on group; little self-direction	1-40 hrs/hr	Low trainee time off; hardware is telephone system	Social interaction; provides feedback; inexpensive; available at numerous sites including home	Scheduling is difficult; lack of visual presentation

31-463 - 90 - 7 : QL 3

Computer conferencing	4	or individual or team	Varies; extensive branching, feedback, self-direction possible	8-300 hrs/hr	Low trainee time off; hardware is $1 ,000-$10,000; courseware is $50 to $10,000	High interactivity; available at numerous sites including home and the work station; excellent transfer to work; adaptable to most subjects; wide content variety; courseware is easy to modify; can be used at any time	Low social interaction; computer intimidation; high cost for dedicated hardware
Simulators	NA	or individual or team	All levels	Months to yeas	Low trainee time off; hardware is $10,000 to millions	High interactivity; excellent transfer to work; avoids danger; presents wide variety of situations; saves real equipment costs	High cost for advanced hardware; low social interaction
Job aids	100	At worksite	NA	usually little	Minimal	Provides on-demand training; easily modified; excellent transfer to work	May not be used by workers
Embedded training	NA	At worksite	NA	Incorporated in equipment development (weeks to years)	Low trainee time off; hardware is incorporated in equipment cost; may add tens to thousands of dollars to those costs	Provides on-demand training; excellent transfer to work	Difficult to design; requires new approach to product engineering with significant advance planning

[a]Based on survey data from Fortune 500 and private companies with sales of $500 million or more.
[b]See box 1-C for a discussion of the various aspects of interactivity.
[c]Hardware and courseware costs usually can be spread over numerous training sessions; also, in the case of TV, videotape, and computer-based training, hardware may be used for other purposes.
[d]These will not occur automatically but depend on the quality of the training program, the appropriateness of the technology to the training function, the skill of the instructor (if any), and other variables.

SOURCE: Office of Technology Assessment, 1990.

Box 7-B-Classroom Training at NUMMI

New United Motor Manufacturing International (NUMMI), a joint venture between General Motors and Toyota in Fremont, California cross-trains maintenance mechanics who are responsible for all plant maintenance plus special projects such as building robots. Trainees spend 5 years studying five trades (plumbing, pipefitting, welding, electrical, and machinist). The program includes about 20 percent lecture (theory) and 80 percent lab (troubleshooting small equipment, making projects), supplemented with on-the-job training. It is much less intensive in any one trade than registered apprenticeship programs, however. Graduate trainees receive a United Auto Workers electrical journeyman card and a State of California multi-craft journeyman card, neither of which would be recognized by other unions.

Before entering the program, candidates take placement tests in both basic skills and their individual crafts. Basic skills deficiencies are remediated in class contexts (e.g., math skills in blueprint reading). Classes are 2 hours a day, at the end of each shift; during the most intensive training, classes meet 4 days per week (for this period, a trainee is in the workplace 48 hours per week). The lab component of each course includes 10-15 projects that the trainee has to complete satisfactorily. Each project has three basic steps: describe the process, make a materials list, then return the finished product for review of quality/quantity. The projects range in difficulty from trouble-shooting small electrical devices to machining parts to welding. Trainees have to pass each class with a score of at least 80 percent or repeat it. Training continues on the shop floor as those mechanics most skilled in one field assist their co-workers in maintenance tasks.

Training aids in the laboratory include basic electrical units (e.g., volt-ohm-meters, circuits, switches, small motors), machine tools, welding booths and equipment, and other equipment and tools common to the factory (most were scrounged rather than purchased).

The maintenance mechanics feel their productivity has improved as a result of cross-training (e.g., one cross-trained worker often can complete repairs that previously required two or three specialized maintenance workers). However, in some crafts-particularly electrical-the mechanics do not feel they have had sufficient training to tackle complicated repairs without assistance from a union-certified journeyman.

SOURCE: Office of Technology Assessment 1990.

Printed materials are highly reliable, relatively inexpensive to develop and reproduce, and are portable and compact. Almost any kind of subject can be discussed in print, and a wide range of material is available. On the other hand, print gets unwieldy for large amounts of information, and it is neither interactive nor dynamic. Overhead transparencies also are handy and have largely replaced the blackboard in training classes. Transparencies are easy to prepare, can be used many times, allow color and graphics, and can be written on the spot. The projectors are reliable, affordable, standardized, and require little skill to operate.

Second, many instructors have had little exposure to instructional technology. Even those who have had courses about training technology usually have not had enough hands-on experience with it to use it confidently or to design courses around it. Moreover, many corporate training personnel have little formal background in instruction. More often they are trained in human resource development or are subject-matter experts assigned training responsibilities.

Third, incorporating training technology in courses can require much more development and preparation. Most instructors do not have the time or resources to prepare such courseware. Even handwritten lecture notes take less time to prepare than good overhead transparencies. As courseware moves into videotape or disc, computer-based material, or teleconferencing, the amount and cost of development and preparation increase appreciably.[2]

Fourth, developing good technology-based training material often requires a team approach. Instructional designers provide the learning approach; subject-matter experts provide the substance; technical experts do the computer programming or produce video materials. Yet teaching traditionally has been a solitary affair.

Fifth, traditional classroom instruction has a major social component. It provides an opportunity to visit with colleagues rarely seen in the normal

[2]Ibid.

workday. Often, break-time conversations are as informative as the classes.[3] Some people also like the opportunity to travel.

Finally, some topics have not yet meshed well with technology-based delivery, particularly management skills.[4]

TRAINING TECHNOLOGY USE IN INDUSTRY TODAY

Few data are available on the extent to which instructional technology is used in industry. Most organizations do not systematically collect data about their training activities (e.g., number of students, types of courses). In large corporations, decisions to use training technology often are made on a departmental basis with no organization-wide accountability. Many applications of technology are considered experimental and are not included in descriptions of training. Other technologies such as overhead transparencies and videotapes are so mundane no one bothers to describe them.[5] Also, many companies do not respond to survey requests for training data.

Nevertheless, two sets of training technology survey data are available for 1989. One survey conducted by *Training* magazine obtained responses from around 1,500 companies with 100 or more employees about the kinds of training delivered, how, and to whom.[6] The survey had a very low response rate. However, the data are included in this report as a rough indicator of the level of use. Figure 7-2 shows the percent of companies using different instructional methods.[7]

A second survey conducted by the American Society for Training and Development (ASTD) polled 200 human resources executives in *Fortune 500* corporations and privately-held firms with annual sales over $500 million about their use of computer-based training (CBT), interactive videodisc (IVD), and teleconferencing.[8] The ASTD results show 81 percent of responding companies using computers in training, 50 percent using IVD, and 33 percent using teleconferencing (see figure 7-3).

One thing seems clear from the survey data—large corporations are more likely to use technology in training. For example, 44 percent of all corporations responding to the *Training survey* do computer-based training, but use increases to 64 percent for responding corporations with 10,000 or more employees. The figures were 11 percent and 34 percent for interactive video training.

Other sources indicate that small businesses are more likely to rely on informal on-the-job training, and on demonstrations and printed documentation provided by equipment vendors. Because personal computers (PCs) and viola cassette recorders (VCRs) are relatively common even in small businesses, they also use CBT courses for computer-related topics (e.g., a specific word processor) and videotapes for sales, customer service, or management skills.[9]

One way that instructional technology can affect small businesses is when it is used by their corporate customers or offered by government or professional organizations. Thus, a small business that supplies parts to a corporation practicing total quality management may have to use a specific training approach to maintain its supply contract. Also, State and local agencies may have extension or other outreach services to aid small business. For example, the Maryland State Department of Education developed an interactive videodisc called "The Business Disc' (TBD) that provides an introduction to starting and operating a business (e.g., type of ownership, location, salaries, capital investment, and cash flow). The videodisc simulates the first

3Beverly Geber, "Goodbye Classrooms (Redux)," *Training,* vol. *27, No.* 1, January 1990, pp. 27-35.

4Kearsley, op. Cit., footnote 1.

5Ibid.

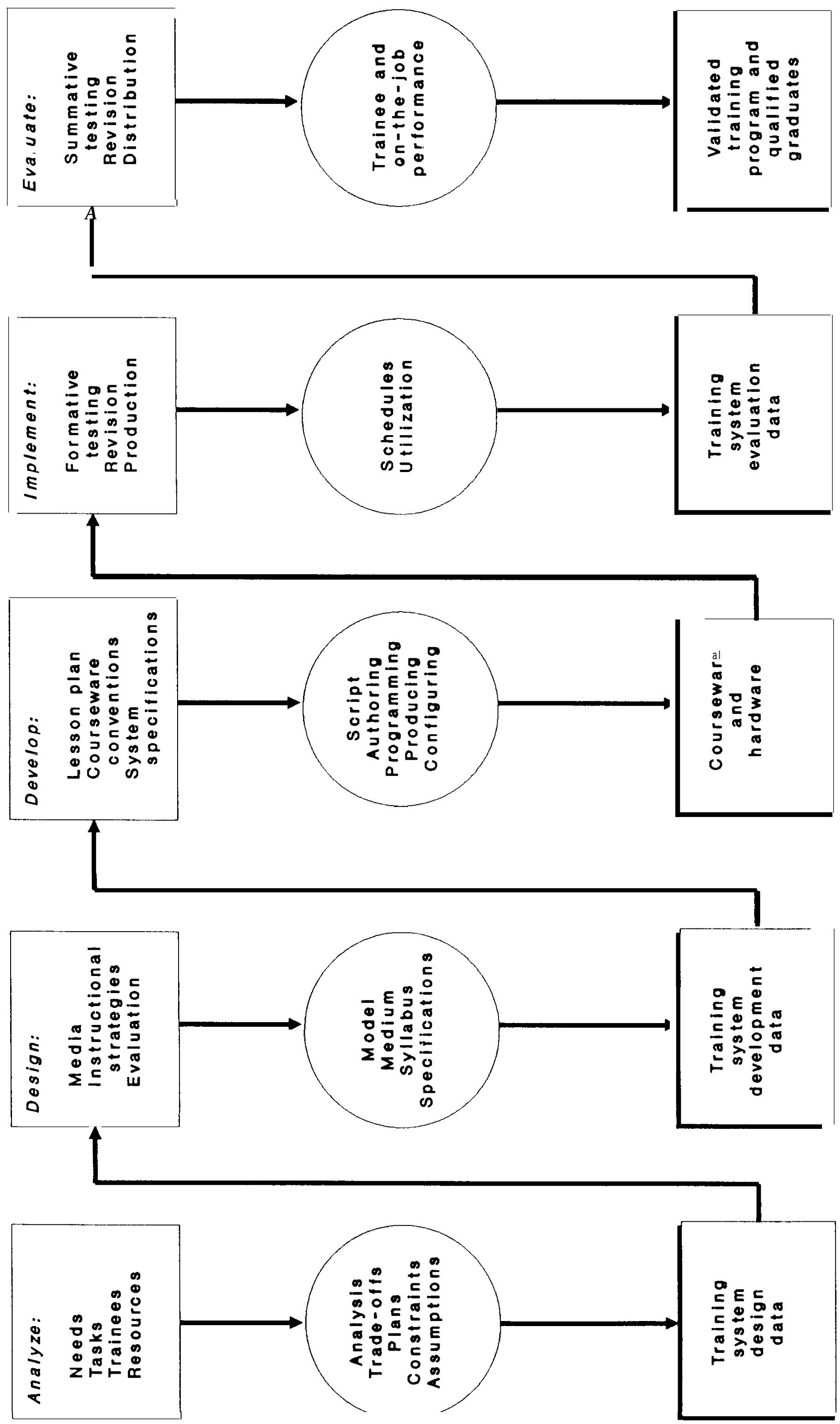
6In 1989, *Training* magazine mailed two versions of a survey to 20,000 organizations culled from a sampling of Dun & Bradstreet's directory of U.S. businesses and the magazine's subscriber list. Both versions included questions about training budgets, topics, and trainees. Half of the surveys had unique questions about interactive video and computers in training, and the other half bad unique questions about instructional methods. The former received 1,542 responses, and the latter 1,588 responses. Because of the low response rate, care should be taken in interpreting the data.

7"Industry Report," *Training, vol. 26, No.* 10, October 1989, pp. 31-63.

8The ASTD survey was distributed to their Human Resource Development Executive Survey panel, which includes 200 members; responses were received from 153.

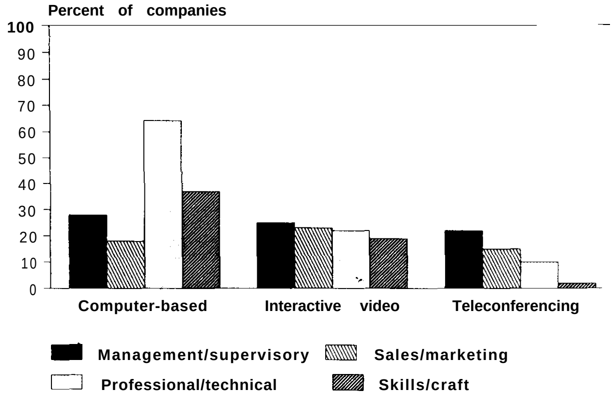
9Kearsley, op. cit., footnote 1.

Figure 7-2—Instructional Systems Development Process



SOURCE: Office of Technology Assessment, 1990.

Figure 7-3-Technology Training Use



SOURCE: Based on American Society for Training and Development survey of 157 executives from Fortune 500 private firms wfth $500 million + in sales.

year in business based on decisions that users of the disc make in the planning stage. Typical business issues are presented such as rent increases, personnel policies, late deliveries, theft, and disgruntled customers. TBD has been used at a number of small business development centers and community colleges. For example, New York State has decided to install IVD workstations for TBD in 21 small business centers. At the community college level, the program is being used in business and marketing courses to allow students to try out business ideas they learn in class.[10]

Some small businesses are franchises, for which the parent organization encourages consistent product quality and management, and can afford to develop and distribute training materials. Chains such as Domino's Pizza, FoodMaker, and Southland Corp. (7-Eleven) use video and are experimenting with IVD to train basic employee skills at the worlmite.11

Television

Despite its popularity as an entertainment medium, 'broadcast television is not widely used for training (except for regular adult education) because of:

- high production costs and time for programming,

Photo credit: IBM

IBM's interactive television classroom

- lack of flexibility in scheduling,
- trainee boredom due to poor programming or instructors or lack of interaction, and
- regulation of the use of television frequencies.[12]

Current cable television use for training consists primarily of continuing education and similar instructional services provided by local community colleges and other educational institutions. In many cable franchise areas, these educational commitments plus commercial programming fill existing capacity. As cable systems expand their channel capacity, introduce two-way capability, switch to fiber optics, provide computer networking, and enroll more households, cable will become an increasingly attractive medium for instructional delivery .13

Satellites are making television-based training much more attractive. Training programs can be delivered directly to company sites without going through broadcast television or cable networks. Satellites also allow teleconferencing (see below) with two-way video for interactivity. Many large organizations have satellite uplink/downlink equipment at branches or plants and use television to

[10] R. France, "Experimenting in Business with IVD: An Evaluation," *Instruction Delivery Systems*, vol. 3, No. 5, September/October 1989, PP. 22-24.

[11] Kearsley, op. cit., footnote 1.

[12] Ibid.

[13] Norman D. Kurland and Associates, "The Role of Technology in the Education, Training snd Retraining of Adult Workers," contractor report prepared for the Office of Technology Assessment, October 1984.

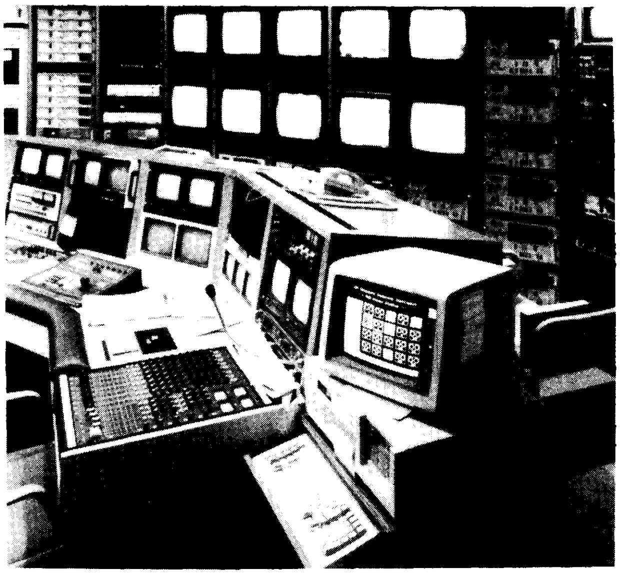


Photo credit: IBM

Video control room for IBM's interactive television classroom.

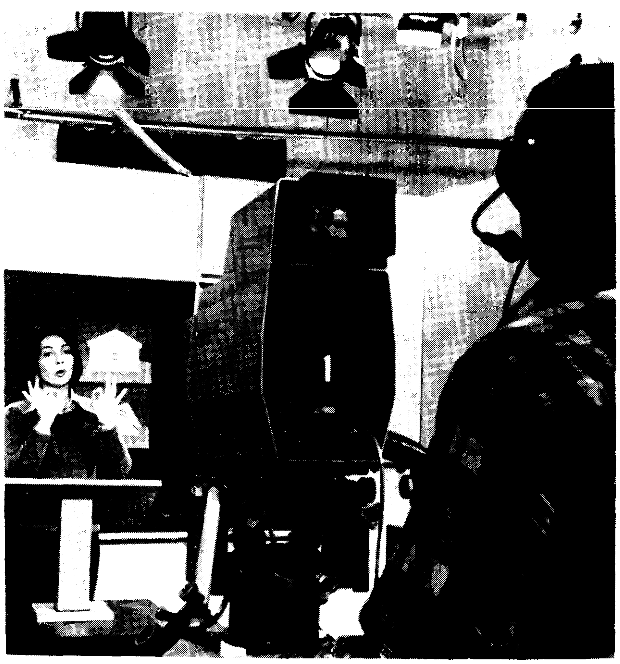


Photo credit: American Association for Community and Junior Colleges

Most instructional television is simply a broadcast version of standard lecture format.

broadcast training courses. This is especially attractive for multinational corporations and agencies with facilities all over the world. For example, IBM has four satellite networks, and Motorola, Ford, Hewlett-Packard, and Kodak also use satellite television in training.

The largest user of satellites for training today is National Technological University (NTU), which broadcasts hundreds of engineering courses to corporations and Federal agencies (see box 7-C). As satellite facilities become more common, more companies will emulate this proprietary network model. However, few organizations have yet addressed the remaining problems restricting television's use in training-high costs and low interactivity. Consumer applications of interactive television are being introduced now (e.g., play-along game shows, viewer-selected camera angles). In the short term, however, even with satellite transmission, television's use for training remains limited.[14]

Video

Videotape is a very popular training medium. Tape is portable and overcomes television's scheduling problems. Videotape players are inexpensive and highly reliable. A wide selection of commercially available programs cover most areas of training. For example, the American Management Association (AMA) and the American Media Center for Engineering Education (AMCEE) offer large libraries of training tapes. Many professional societies (e.g., Institute of Electrical and Electronics Engineers, American Bar Association) offer videotape self-study courses to meet continuing education requirements for their members. Most large companies and government agencies produce an extensive number of instructional tapes for their own use. Because many American homes have VCRs, videotape also is a viable medium for self-study .15

Despite its wide use, videotape has limitations as a training medium. It essentially is a linear presentation mode with only limited opportunities for student interaction. Systems have been developed to permit random access to tapes, but they are cumbersome compared with videodisc.[16] While it has been used successfully in technical training (e.g., mechanical repair and maintenance) when focused on narrow tasks, videotape is unsuitable for presenting a lot of factual information. As with television

[14] Kearsley, op. cit., footnote 1.

[15] Ibid.

[16] Kurland, op. cit., footnote 13.

Box 7-C—Natiional Technological University

The National Technological University (NTU) broadcasts programs originating at universities via satellite to corporate subscribers. There currently are 29 member universities, 55 corporations, and 15 other sponsoring organizations, with 242 receiving sites. In 1989, NTU offered around 450 graduate courses, plus numerous continuing education classes in non-credit Advanced Technology and Management Programs. Of the 3,000 graduate students, 655 are enrolled in degree programs. NTU estimates that around 30,000 people currently are taking short courses. NTU averages over 250 hours of live broadcasting weekly-more live programming than ABC, NBC, and CBS combined.

NTU graduate courses focus on engineering and computer science. They are taught by faculty members from the member universities. Even though the courses originate from universities, NTU grants the degree (M. S.—accredited-in either Engineering, Management of Technology, and Materials Science and Engineering). Corporate sponsors pay site fees to receive the programs and provide their own downlinks and classrooms. In courses requiring lab work the sponsoring organization agrees to maintain lab facilities, either onsite or through arrangements with nearby colleges or private facilities. The labs are subject to inspection by NTU at any time.

NTU also hosts many teleconferences (one-way video/two-way audio) as special programs for continuing education. The topics tend to be leading edge subjects in engineering and technology, such as superconductors, supercomputers, distributed networks, artificial intelligence, and automated manufacturing. These teleconferences allow engineers and their managers to stay abreast of the latest developments without having to leave their offices. The teleconferences add an interactive component to the broadcasts by allowing participants to ask questions and share experiences, making the courses more interesting and relevant. NTU also delivers interactive technical assistance programs to business entrepreneurs.

In general, students praise the course subjects and the instructors (who often are leading experts in their field). However, most courses still follow the traditional television and videotape "talking head" format with little or no interactivity; they can be dull. Also, some university camera and transmitting equipment is substandard, resulting in poor picture quality. NTU is encouraging the member universities to upgrade their equipment and many have done so.

Enrollment in NTU courses continues to increase; the number of graduate students admitted to degree programs doubled in 1989. NTU predicts that by 1993 it will be providing 10 percent of the advanced study opportunities for part-time graduate engineering students in the United States. Based on the 655 students actually admitted to degree programs today, within 5 years NTU will be among the top 10 schools in the nation in terms of number of M.S. Engineering degrees awarded. Although NTU is limited to engineering-related topics, it could serve as a model for professional education in fields such as law and finance.

SOURCES: Greg Kearsley, "Instructional Technology and Worker Learning Needs," report prepared for the office of Technology Assessment under contract L3-5615, February 1990; and NTU annual report for 1989.

programming, videotape requires substantial development time and cost and is difficult to customize for specific situations.[17]

Less common (and relatively new) is interactive video training. About 34 percent of the large corporations responding to the *Training survey* were using some form of interactive video training (but only 11 percent for all responding companies with 100 or more employees). Of the responding interactive video users, 47 percent use a combination of videotape and personal computer, while 61 percent use videodisc. About 72 percent use interactive video for self-paced instruction and 40 percent in group or classroom instruction. The overwhelming majority (95 percent) use at least one off-the-shelf program; 29 percent have custom-designed program.[18] In the ASTD survey, interactive video applications were evenly divided among training for managers and supervisors, sales and marketing staff, professionals and technical workers, and skills and craft employees.

Analog videodisc has been used in training for several years. Interactive videodisc excites trainers because it combines the audio-visual power of television with a high level of interactivity that can be used in diverse delivery settings. It can present a

[17] Kearsley, op. cit., footnote 1.

[18] "Industry Report, " op. cit., footnote 7.

lot of text or graphic information as well as still or motion video and audio-often simultaneously (see table 7-2).[19] Compact discs for computers (CD-ROM) and digital videodisc (just now being introduced) provide even more storage capability (see table 7-3 and discussion of future technologies, below). The contents can be accessed randomly, information can be layered to give options on the depth and/or breadth accessed, items can be linked for browsing or cross-reference, and branching can be used for interactivity. Its other attractive properties include high information density and durability.[20]

Over the last few years, private developers and the government have produced numerous commercially available IVD training programs. For example, a courseware guide published by IBM lists over 500 multimedia programs related to personal computers, data processing, education, health/medical topics, industrial technology, management/professional skills, and other subjects.

The primary obstacle to further IVD use is cost—it requires more development time and more expensive equipment than videotape or computer-based training. Even if the price were reduced 50 percent, it would be beyond the resources of many companies that have a small trainee population over which to spread the cost. Furthermore, IVD usually is used for guided self-study, while the bulk of formal training is still conducted in classroom format. Therefore, IVD is unlikely to be adopted widely without a firm corporate commitment.[21]

The lack of industry-wide standards also is a continuing deterrent to greater investment in IVD. Each hardware manufacturer initially used a different operating system, and programs developed for one system would not play on others. The Interactive Video Industry Association is developing a standard set of operating commands, which most hardware and courseware producers are expected to adopt. The Association also is working on software that will translate existing programs to the standard commands. Variations in international television standards also make it difficult to deliver IVD to overseas locations. Users must either ship compatible hardware or custom tailor courseware to local conventions.

Table 7-2—Potential for Analog Videodisc Frame Use

Motion (minutes)	still frames	Compressed audio (hour)	Digital data (Mb)[a]
30	0	0.00	0
25	1,625	13.53	10
20	3,250	27.08	20
15	4,875	40.61	30
10	6,500	54.16	40
5	8,250	68.75	48
0	9,875	82.28	58
0	54,000	0.00	0
0	0	150.00	0
0	0	0.00	221

[a]Mb = megabyte.

NOTE: This table shows howthe 54,000 frames on an analog videodisc can accommodate various combinations of motion and still video, audio, and data. For example, a disc containing only one medium could hold 54,000 still pictures, or 30 minutes of motion video, or 150 hours of compressed audio, *or* 221 Mb of digital data. Alternatively, the media can be combined in various ways; e.g., 10 minutes of motion video *and* 6,500 still frames *and* 54 hours of compressed audio *and* 40 Mb of data.

SOURCE: U.S. Video Corp.

But many organizations believe that the training results are sufficiently improved to just@ the additional cost and equipment. For example, General Motors Corp. uses IVD extensively throughout the corporation for technical and sales training. The United Auto Workers (UAW) and GM have setup a joint Center for Health and Safety that offers dozens of self-study courses using IVD. According to industry figures, GM alone has bought over 10,000 videodisc players for use in training. Ford and Chrysler also use ND extensively for training. Finally, the military has made a major commitment to using IVD in training (see report appendix); the Army EIDS project ultimately expects to field 50,000 players (see box 7-D).[22]

Interactive video appears to be especially valuable in several particular training areas. It has been used extensively in the design of simulations (see below) for maintenance training. For example, Federal Express developed an IVD course to teach its aircraft mechanics how to troubleshoot and repair

[19]Joseph V. Henderson, "Design and Production of Interactive Multimedia Simulations," tutorial presented at 11th Conference on Interactive Videodisc in Education and Training, Arlington, VA, August, 1989.

[20]Kurland, op. cit., footnote 13.

[21]Kearsley, op. cit., footnote 1.

[22]Ibid.

Table 7-3-Capacities of CD-ROM, DVI, and CD-1

Medium	CD-ROM	DVI	CD-1
Text	325,000 pages	650,000 pages[a]	300,000 Pages[a]
Audio	72 minutes of CD quality	5 hours FM stereo, or 20 hours mid-range monaural, or 40 hours near-AM quality monaural	96 hours AM quality
Still pictures	500 high resolution	5,000 very high resolution, or 10,000 high resolution, or 40,000 medium resolution	7,000 very high resolution
Motion video with companion audio	30 seconds	1 hour full screen/full motion, or 4 hours, 1/4 screen/full motion, or 16 hours 1/8 screen at 1/2 frame rate	No full screen/full motion Can show partial screen/full motion Better suited to full screen/full motion animation
Mixed media example	Not available	20 minutes full motion video, and 5,000 high resolution stills, and 6 hours audio over stills, and 15,000 pages of text	Not available

ABBREVIATIONS: CD. compact disc; CD-ROM = compact disc read-only memory; DVI = digital video interactive; CD-1= compact disc interactive.
[a]The amount of text is actually the same for DVI and CD-1, but appears different due to the allotted characters per page.

SOURCES: G. David Ripley, "DVI—A Digital Multimedia Technology," and Karen A. Frenkel, "The Next Generation of Interactive Technologies," both in *Communications of the ACM*, vol. 32, No. 7, July 1989.

Box 7-D—The Electronic Information Delivery System

In the early 1980s, the U.S. Army began seeking a multimedia training delivery system to replace the slide-tape unit in use for many years. In 1983, the Army asked several companies to develop interactive videodisc prototypes. After field testing, a specification for the Army Electronic Information Delivery System (EIDS) was established in 1986. In December of that year, the Army awarded a contract to Matrox Electronics of Canada to supply the hardware and software. The initial contract called for a total purchase of 48,000 units over 4 years with a value of $223 million.

The EIDS work station consists of an IBM PC/AT-type computer employing EGA/VGA graphics and a 12-inch optical laserdisc player. The system is capable of overlaying graphics on video displays, playing over 1 minute of sound per still frame, and storing/reading computer programs on the videodisc (Level IV capability). In its most basic configuration, it has a commercial price of about $6,000 per workstation.

Actual EIDS delivery and courseware development has lagged behind due to procurement difficulties. In 1988, 14 solicitations to develop courses were authorized but none was awarded due to lack of funds. But, by 1989, approximately 10,000 units had been delivered to Army Training and Doctrine Command (TRADOC) schools and Army and Navy Reserve sites.

One of the strengths of EIDS is that several authoring systems are available. Computer Sciences Corp. developed the primary one, ASSIST, for the Army; it is provided to contractors for courseware development. At least 10 other commercially available authoring systems also can be used with a standard MS-DOS computer and laser optical videodisc player to create EIDS courseware. Several companies have developed "generic" courseware that can run on EIDS, and numerous vendors are capable of developing custom courseware for the military or for civilian clients.

EIDS could be a billion-dollar business opportunity for the IVD industry. How much courseware actually is developed will depend on EIDS' acceptance by the military training system and the amount of funding allocated for courseware. However, without specific technology transfer initiatives or an eager corporate champion, it is unlikely that EIDS will be applied to civilian training needs. The choice of Matrox Electronics as the primary contractor has not helped technology transfer because the company is practically unknown in the United States and has made little attempt to market the system outside of military circles. Furthermore, economies of scale have not materialized. Indeed, EIDS is more expensive than comparable systems available from other vendors or assembled from off-the-shelf components.

SOURCE: Greg Kearsley, "Instructional Technology and Worker Learning Needs," report prepared for the Office of Technology Assessment under contract L3-5615, February 1990.

electrical problems. The course allows mechanics to take readings, test components, replace equipment, and evaluate procedures.[23]

The visual and motivating characteristics of IVD also make it valuable in improving basic skills.[24] For example, the Wisconsin Foundation for Vocational Technical and Adult Education has developed an IVD course called Interactive ModuMath designed to improve students' basic math skills. A wide variety of students in Wisconsin technical colleges use the course, and both students and instructors reportedly like it.[25]

Another interesting use of IVD is on the factory floor to support computer-integrated manufacturing (CIM). Apple Computer and Martin-Marietta both have high-tech plants that provide employees with workstations capable of displaying brief video sequences about different manufacturing processes. These sequences can provide "just-in-time" training to correspond to the complex nature of a CIM operation, which involves frequent shifting from one operation to another. Each station replaces hundreds of pages of printed material.[26] Central monitoring allows supervisors to pinpoint problems and deliver needed parts, but it also can provide data on employee performance and thus contribute to employee stress.

Finally, IVD is becoming valuable in teaching interpersonal skills, such as sales. Workshops are the most traditional training approach for such skills, but workshops are of inconsistent quality, provide little subsequent reinforcement, and have limited practice opportunities. Thus, any excitement and motivation workshops generate may not be transferred to job performance. IVD combined with role-playing now promises to provide an effective means of training in interpersonal skills (see box 7-E).[27]

Computers

Of all the technologies, computers have excited the most interest for instructional applications. Computers' vast capacity for handling information,

Photo credit: American Association for Community and Junior Colleges

Computer-based training can be delivered at the work station, or in a classroom or laboratory.

the variety of ways they can be programmed to respond to user commarids, and their rapidly declining cost and increasing power, make them seem to be the ideal "teaching machine." To the extent that PCs or other terminals already are available in the workplace, they become a natural and convenient way of delivering training. If computer equipment must be bought specifically for computer-based training (CBT), however, it is a relatively expensive approach.

Computer-based training can incorporate any information that can be stored on a floppy or hard disk-e.g., text, graphics, data. Recent advances in software design provide windows and branching. Developments in storage technology (e.g., CD-ROM and optical drives) add audio and still video capability. Connection with a videodisc player allows Ml-motion video. With artificial intelligence

---

[23] Ibid.

[24] The use of instructional technology in basic skills training is discussed in more detail inch. 6.

[25] Ibid.

[26] Ibid.

[27] William Ives, "Soft Skills in High Tech: Computerizing the Development of Interpersonal Skills," *Instruction Delivery Systems,* vol. 4, No. 2, March/April 1990, pp. 12-15.

Box 7-E—Automating Interpersonal Skills Training

Teaching effective interpersonal skills, such as selling, remains one of the biggest challenges in training today. In many of the top insurance companies, for example, at least 75 percent of the new sales personnel leave after 3 years, largely because they are unable to develop sufficient sales skills to make an adequate income from their commissions.

A combination of automated audio/video feedback and interactive videodisc or computer-based training (CBT) is now being used to teach sales skills (or to aid in early recognition that one is not suited to sales). One IVD system uses a laserdisc player, touchscreen monitor and a PC coupled with a videotape recorder, camera, and microphone. The IVD presents full-motion/audio demonstrations of skills such as presenting credentials, then provides review exercises with proper and improper examples of those skills. Trainees can interrupt the presentation of a skill when a mistake is made and offer a critique of the action. Feedback is given on the appropriateness of their critique.

The camera or audio recorder is then used to allow the students to demonstrate proper behavior. Trainees face anew customer (provided on the IVD) and practice the skill they just saw modeled.[1] Their performance is recorded on videotape along with the customer's conversation. Students can practice in privacy, then review their performance based on a set of criteria (from the IVD) and evaluate their own behavior. They can erase and repeat, practicing as many times as they wish. When they feel they have successfully transferred the training to their performance, trainees can show the tape to the supervisor, who provides advanced coaching.

In a pilot evaluation program, insurance agents using this training program had a 16 percent increase in calls, a 24 percent increase in kept appointments, and a 43 percent increase in approach interviews with clients. In addition, new hire training time was reduced 30 percent over traditional classroom methods, and the subsequent on-the-job learning curve decreased. For example, one agency that had been using the IVD system for over a year compared 10 agents who used the system with 17 trained by traditional methods. The 10 using the IVD program were at a level 18 months ahead of the control group after the completion of training. While it is difficult to separate the impact of the IVD training from other changes in the company, its revenues also have gone up since introduction of the system, and the agent retention rate has increased.

IBM also experimented with an IVD system coupled with a videotape camera for teaching sales skills. In a comparison with their traditional person-to-person role playing training, they found that trainees using the IVD system did much better in structuring their sales calls and developing sales skills.

A second, similar, program uses CD-ROM combined with audio feedback. Full-motion video will be available on CD-ROM within a couple of years. For some training situations, such as telephone sales, audio feedback is actually closer to the real job situation, and full-motion video is not needed. CD-ROM also costs approximately $2,000 less per training station than IVD, has larger storage capacity, and can be used more easily for non-training applications.

[1] Although the "customer" on the IVD cannot respond in all of the unexpected ways a real person might, this@ change with advances in artificial intelligence.

SOURCES: William Ives, "Soft Skills in High Tech: Computerizing the Development of Interpersonal Skills," *Instruction Delivery Systems*, March/April 1990; and Beverly Geber, "Goodbye Classrooms (Redux)," *Training*, vol. 27, No. 1, January 1990.

and hypermedia software, CBT can provide fourth- or fifth-generation interactivity (see box 7-B).

The advances in computer hardware and software also have revolutionized other areas of training. Computers control the interactivity in CBT and IVD. Sophisticated computer graphics and databases are integral parts of simulators. Packages such as authoring systems have largely obviated the need for computer programming in instructional design. Database management programs make it much easier to keep track of the elements when developing a complicated CBT or IVD program. Relational databases provide the underpinnings for performance support systems.[28] Computer technology also is at the heart of emerging systems such as electronic classrooms, digital networks, and virtual environments.

[28] Relational databases are currently the most powerful and flexible means of integrating the various components Of a @O rmance support system. In a relational database, the data are represented as tables in which no entry has more than one value. This makes it easier to link data so that complex queries can be handled rapidly.

Table 74-Computer Use in Training at U.S. Companies With More Than 100 Employees[a] (percent)

Number of employees	Use computers in training[b]		Doing CBT		Use computers in data management		Use computers in word-processing or graphics		Not using but will by 1990
	1988	1989	1988	1989	1988	1989	1988	1989	1989
100-499	59.6	64.8	37.9	43.3	49.7	55.2	53.4	62.7	5.8
500-999	57.4	67.7	31.0	43.6	47.3	61.5	52.7	64.6	8.7
1,000-2,599	67.1	73.6	45.1	48.0	57.2	64.1	59.0	67.4	9.2
2,500-9,999	77.6	74.2	56.5	52.1	71.4	64.7	72.0	66.6	4.9
10,000 or more . . .	82.9	82.6	58.3	64.0	76.6	75.2	79.4	76.4	3.8
All sizes	60.8	66.2	38.6	44.1	51.1	56.9	54.6	63.4	6.2

[a]The data in this table oome from a survey that had a very low response rate. Thus they only provide a rough estimate of the extent of CBT.
[b]Refers to organizations reporting that they use computers in some way in connection with theirtraining efforts. This might include recordkeeping or other data management, word processing, or creating graphics for training classes.

SOURCE: "Industry Report, 1989," Training: *The Magazine of Human Resources Development*, vol. 26, No. 10, October 1989, p. 58.

All of these features combine to create a training medium with a vast capacity for imparting information in a truly interactive form. Moreover, the courseware can be edited or updated easily and at a much lower cost than videotape or videodisc. Finally, courseware can be sent anywhere in the world that compatible hardware is available, and can be used at the learner's convenience. These advantages can give CBT a substantial edge over television or videotape training.

Provided that courseware can be developed or purchased for a cost comparable to classroom instruction or videotape, CBT is likely to displace those methods of instruction in companies where terminals are available. The development of instructional design and authoring tools that reduce the cost and time to develop CBT is thus a key factor in making this training technology successful on a wider scale.

According to the *Training survey,* about two-thirds of responding companies with 100 or more employees were using computers in some aspect of training (see table 7-4). Most of the companies use computers for word processing or to create graphics; many also use them for data management (e.g., program evaluation, test scoring, survey processing). Around 44 percent of the companies use CBT. Of those, 80 percent use it to teach people to operate computers, 38 percent to deliver training on non-technical subjects (e.g., management or interpersonal skills), and 37 percent to provide training in technical skills.[29] The ASTD survey indicates that 67 percent of the companies surveyed use CBT most often to train professionals and technical staff; 37 percent report its use for skills and crafts training.

A barrier to CBT use arises when workers are not familiar with computers. They often are afraid of the technology and are intimidated by a keyboard. The use of touch screens and light pens and the growing use of computers to provide public information at sites such as shopping centers and museums is overcoming this problem. Also many CBT users have been turned off by poorly designed programs that only transferred printed material to disk (see description of first-generation courseware in box 7-B). As with other training media, it is essential that CBT incorporate good instructional development principles, and that training managers follow such principles in developing or purchasing courseware appropriate to the skills to be imparted.

Today, CBT is used for a wide range of applications in industry, including technical, basic educational, and interpersonal skills (see boxes 7-E and 7-F). Although it was the PC that gave rise to CBT's current popularity, one of the largest uses still is on mainframe computers to teach data processing and other job-related skills in the insurance and banking industries (see box 7-G).[30]

CBT also is used in basic skills training (see ch. 6). Efforts are underway to transfer the U.S. Army's Job Skills Education program (JSEP) to adult and vocational education. McGraw Hill, in conjunction with Apple Computers, is developing a series of print and CBT programs to improve basic skills in six areas (health, automotive, business, construction trades, electronics, and office). The Adult Literacy

[29] "Industry Report," op. cit., footnote 7.

[30] Kearsley, op. cit., footnote 1.

Box 7-F-Computer-Based Training in Industry

Computer-based training (CBT) can be used to impart technical and other skills. Some examples include:

- *Anheuser-Busch in* St. Louis, Missouri is using a Micro TICCIT system to teach assembly-line workers to run beer can packaging machines. The choice of CBT is driven by a desire to improve quality control in manufacturing and an overall modernization effort in plants. This particular training task was chosen because it is one of the most critical aspects of beer packaging.
- *Burlington Northern* uses a MicroTICCIT system to teach train crews the rules of operation for railroads (e.g., switching signals). This is mandatory knowledge fora all train crew personnel, but classroom instruction had not proven very effective. CBT both upgrades the quality of training and facilitates its distribution to the field.
- ***The** Federal Aviation Administration has* used PLATO to train flight inspection and maintenance specialists for almost a decade; recently they began using CBT for air traffic controllers as well. Courses are delivered to approximately 50 sites around the country. The heavy training load—which is difficult to meet with classroom instruction-was the primary factor in choosing CBT.
- ***Bell Atlantic*** has developed a PC-based financial sales skills course for its telemarketing representatives. The course includes CBT case studies that simulate the selling process and a Lotus 1-2-3 cash-flow template to calculate lease versus purchase options. The company reports that the course improves the competence and confidence of sales representatives.
- ***The Strategic Management Group*** (SMG), in conjunction with the Port Authority of New York/New Jersey has developed a PC-based course entitled "Export to Win" to teach business people about exporting products to international markets.
- *Applied Learning offers hundredss* of data processing courses that run under the Phoenix mainframe CBT system. These courses are used to train staff about mainframe operating systems, applications software, and telecommunications.

SOURCE: Greg Kearsley, "Instructional Technology and Worker Learning Needs," report prepared for the Office of Technology Assessment under contract L3-5615, February 1990.

and Technology Project coordinated by People's Computer Co. of California involves the use of commercially available education software in vocational education programs at community colleges and other training centers. The Technology for Literacy Center in St. Paul, Minnesota, uses computers in teaching adults and reports improvement in terms of continued enrollment, student satisfaction, and increased achievement.[31]

Computers also can be used to manage training. Computer-managed instruction (CMI) allows the instructor and/or trainee to track each trainee's progress through the various paths in an instructional sequence and to ensure that the right lesson and material are assigned and available at the tight time. With advances in storage technology and courseware design, CBT or IVD training programs increasingly have integrated computer management systems. They also can be used with lecture/lab, television, or other training methods.

CMI can range from simple reports on test performance to detailed monitoring and analyses of trainees' progress on hundreds of learning objectives, including comparing each trainee with the class, with all the trainees in a program, and with corporate or national standards. In many systems, not only can instructors, learners, and administrators obtain reports organized in any way that is useful to them, but they also can manipulate the data to get answers to questions that will help them improve course design or delivery and instructional program management.[32]

Such management is critical in any large-scale effort to tailor instruction to individual learners and to allow them to keep track of their own progress. With advanced interactive (third-generation and above) CBT or IVD courseware, learners begin with pretesting that ensures they start with a lesson that will neither bore them nor be beyond them. Then each time they sign on, the system can either start them where they left off or provide review of

[31] Ibid.

[32] Kurland, op. cit., footnote 13.

Box 7-G-Computer-Based Training in the Insurance Industry

The insurance industry has embraced computer-based training (CBT) more whole-heartedly than perhaps any other economic sector. Several factors explain its success in that industry. First, insurance companies already have a strong training tradition. When this is combined with the fact that insurance companies are heavily computerized, with almost every employee having a terminal, CBT becomes natural and cost-effective. Also, both CBT and the material to be learned-policy information and procedures—are well-suited to tutorial strategies.

CBT in the insurance industry has the same advantages as in other sectors: employee scheduling, tutorials and practice exercises to aid learning, and time/cost savings relative to classroom instruction. The first is probably the most important from the employees' perspective and the last from the firm's.

A large insurance company in the metropolitan Washington, DC area serves as an example. The company first got started with CBT in 1981 with an introduction to claims processing course. It failed, however, because the system was not reliable. A few years later, another course-still in use today-was tried on a more stable system. Today the system delivers around 20 courses with about 5 new courses being added annually. Thousands of employees are trained on the system.

While CBT provides effective training for this company, there is an ongoing problem developing and maintaining quality courses. The company finds it difficult to locate authors/designers who know how to develop good CBT and can work with the corporate computer system. One segment of the company relies solely on commercial courses that are then customized. Such purchasing reduces the development costs, but is limited to "generic" course topics (e.g., data processing, customer service).

The insurance industry has tried to encourage courseware sharing through the Society for Insurance Training & Education (SITE), which published a courseware catalog in 1987, with a new version in the works. This effort has not been very successful, however, because of system incompatibilities; confidentiality problems, poor courseware quality, and lack of customization capability. The industry hopes that vendors will market more generic courses and provide customization, but those services will not resolve industry concerns about confidentiality.

SOURCE: Greg Kearsley, "Instructional Technology and Worker Learning Needs," report prepared for the Office of Technology Assessment under contract L3-5615, February 1990.

material they may have had difficulty mastering. Thus the system not only allows more options for instructor management, it also puts the pace of learning in the hands of the trainee-a factor that is particularly important for many adult learners.[33]

Teleconferencing

All forms of teleconferencing have been explored for training. The *Training survey* shows 11 percent of responding firms using videoconferencing, 9 percent audioconferencing, and 4 percent computer conferencing. In the ASTD survey, 33 percent of the firms use teleconferencing of some form, primarily for management and supervisory training.

Audioconferencing is relatively inexpensive, but is limited by the lack of visual presentations-most people find it hard to participate actively without visual cues to indicate who is to speak next. Moreover, the instructors have no way of telling if anyone is paying attention. Finally, demonstrations or hands-on experience can only be achieved for purely audio skills (e.g., telephone sales).

The Kansas Board of Regents has for years operated a statewide audioconferencing system, primarily for part-time adult learners. The courses focus heavily on continuing education in various professions. Students may participate either at conference centers located throughout the State or from their own phones. The primary advantage of the system is that it enables people to take courses who would not otherwise be able to do so or could do so only if the instructors went to numerous off-campus locations. Studies over the years indicate that students in the telecourses do as well as on-campus students.[34]

As the U.S. Public Switched Telephone Network (PSTN) becomes more digital with more capabilities, it may become less a telephone network and more a general purpose broadband network capable

[33]Ibid.

[34]Ibid.

of carrying all types of traffic, including audio, data, and video. Transmitting a live telecourse with full audio and video interaction may be no more difficult than making a telephone call is today .35

For training applications, teleconferences involving one-way video (i.e., broadcast television) with two-way audio (telephone) links are perhaps the best compromise in terms of cost and quality of information transmitted. This allows full presentation of visual information and lets participants ask questions or make comments at any time. A fax machine allows two-way transmission of hard-copy at little additional cost.[36] Compressed two-way video also is becoming more economically feasible for larger companies.

Many large corporations, including IBM, Motorola, and AETNA, have satellite-delivered television networks that are used for training teleconferencing. AETNA, for example, delivers a business writing skills course to over 1,000 employees at more than 50 branches via teleconference. In a classroom, the course takes 2 days; via teleconferencing it reduces to two 1.5-hour sessions (with some preclass work) .37

Until recently, teleconferencing was used only by the handful of organizations that could afford the equipment and could find instructors willing to try it. With the advent of large-scale digital networks and satellite links, the use of teleconferencing for training is likely to become more commonplace. However, it still will require significant preparation time and relatively complex logistics, which may deter many training departments. Nevertheless, increasing pressure to reduce travel time for training is likely to be a major boon for teleconferencing.[38]

Computer conferencing also is relatively inexpensive if the hardware is available, and it gets around the scheduling problems of audio- and videoconferencing. With the increasing prevalence of personal computers, more organizations are beginning to use computer conferencing as part of distance learning activities. For example, the Western Behavioral Sciences Institute has used computer conferencing for several years for high-level management seminars. Participants do not have to take time away from their jobs. Moreover, they can relate what they are learning in the seminar directly to their jobs because many of the exercises involve analysis of real problems in real time.[39]

The International School of Information Management in Irvine, California has a masters degree program using computer conferencing to conduct seminars and provide student/instructor interaction. Boise State University has a masters degree program in Instructional Technology that also uses computer conferencing for remote delivery of courses. This program is supported by, and designed to meet the needs of, the U.S. Army and the National Guard. Because most large corporations already have electronic mail systems in place, the potential exists to use these systems for training activities.[40]

Simulators

Until recently, good training simulators were too costly except for the most dangerous situations (e.g., flight training, nuclear reactors). With the advent of microchips and videodiscs, however, simulators' costs have come down (although the most sophisticated simulators are still too expensive for all but a few civilian applications). Moreover, manufacturers have developed commercial software packages for a variety of simulations.

The *Training survey* shows 44 percent of responding companies using simulations or games of some type. While many of these may not be technology-based, the response rate illustrates the growing recognition of the value of simulation in training. Simulators give trainees hands-on experience without the risk of personal harm or damage to an actual machine or system. Moreover, simulators help trainees prepare for equipment failure and other unpredictable events. Simulators can present a wider variety of malfunctions than is possible on operational equipment or systems. Also, with today's

[35] U.S. Congress, Office of Technology Assessment, *Linking for Learning: A New Course for Education*, OTA-SET-430 (Washington, DC: U.S. Government Printing Office, November 1989). See also U.S. Congress, Office of Technology Assessment, *Critical Connections: Communication for the Future*, OTA-CIT-407 *(Washington DC:* U.S. Government Printing Office, January 1990).

[36] Kearsley, op. Cit., footnote 1.

[37] Ibid.

[38] Ibid.

[39] Ibid.

[40] Ibid.

technology, the time between failures is so long that maintenance personnel rarely see some types of breakdowns. Rather than getting training they probably will forget by the time they need it, technicians instead can go through a simulation of a failure when it occurs.

In addition, simulators can be used at any time and can accelerate the rate of learning since more training opportunities can be provided in a shorter time than with real equipment. They can be designed to focus on specific learning objectives, and they provide consistent and accurate feedback on trainee performance.

Further, simulators may be less costly to produce and operate than actual equipment. Flight and driver simulators save wear-and-tear and fuel; gunnery simulators save ammunition. Simulators also can incorporate CMI and automatically maintain trainees' records, providing more information about their performance than is possible with actual equipment.

Common examples of simulators are in the training of:

- air crews for all types of aircraft;
- ships' officers in docking and navigating supertankers, with sophisticated simulators reproducing the conditions of the major world waterways including detailed graphic or video presentations;
- operators of nuclear and other energy plants;
- technicians in the operation of communications satellites;
- space shuttle crews;
- process operators in chemical plants and refineries;
- boiler operation and maintenance crews (see box 7-H); and
- driver simulators (box 7-1).[41]

The fields of computer graphics and animation now use low-cost simulators to prepare people for more powerful graphics design machines. High-speed animation also is useful in creating environments where it is impossible to film at all, e.g., to create an interactive microscopic world, or to model the human anatomy. Imaging systems can convert data into pictures that help people grasp even very abstract concepts. In medicine, for example, one aspect of physician training is learning how to relate blips on a screen with the organ generating the blips. Students can see arteries expand and contract under differing stimuli. These images are not merely simulations, but computer transformations of data into pictures. Thus students can achieve understanding of processes and interactions much more directly than ever possible before.[42]

Box 7-H—A Boiler Simulator

Lack of training was causing accidents and unacceptable downtime in organizations that use recovery boilers.[1] The problem was severe enough that insurance companies were threatening to cut off insurance for the machines. Yet recovery boilers are sophisticated pieces of equipment that cost $90 million and are 14 stories high; training operating and maintenance/repair personnel on a real boiler is dangerous, and demonstrating malfunctions could become expensive.

The J.H. Jansen Company of Woodinville, Washington, which makes Kraft recovery boilers for the paper industry, developed a boiler simulator called Recovery Boiler Tutor (RBT). The simulator, which uses an expert system, presents trainees with scenarios representing boiler inefficiencies, problems, or emergencies. These difficulties can be resolved in 20 to 30 moves, with the learner choosing options such as "add oxygen" or "open flue." When trainees get off track the system prompts them with comments such as "Have you noticed that the trend lines are askew?" or "The oxygen is much higher than it should be."

Learners have three options for interacting with RBT: they can ask for a scenario that starts with a particular problem to solve or one that starts with the boiler operating normally and then develops a problem that must be diagnosed, or they can adjust simulated dials and meter readings to create a problem.

RBT took 18 months to develop, and is now used in more than 80 plants in the United States, Canada, and Europe. Within months of its first installations, several insurance companies offered discounts to plants that trained with RBT

[1] Recovery boilers are used to recycle chemicals by removing process water and concentrating them.

SOURCE: Peter R. Kirrane and Diane E. Kirrane, "What Artificial Intelligence is Doing for Training," *Training*, vol. 26, No. 7, July 1989.

[41] Ibid.

[42] Ibid.

A new twist in the use of simulators is the capability to network individual simulators for teamwork. DoD currently is implementing a concept called SIMNET, which connects simulators of armored vehicles as well as tactical aircraft and artillery and their field commanders to operate together for real-time combat exercises (see box 7-J). Networked simulators eventually could be relevant to civilian teamwork situations such as surgery and major equipment malfunctions (e.g., mass transit breakdowns, wide-area electric power blackouts); in the meantime, the computer graphics and network aspects are likely to make important contributions to the technology base.

Job Aids

Job aids are valuable whenever the skill or knowledge required is used infrequently, so that even if people were trained, much of what they are required to do might be forgotten when needed. Job aids also are used where workers must remember many detailed steps and do them in proper sequences. At the high-tech end, some forms of job aids are evolving into embedded training (see below).

Virtually every worksite uses job aids of some type, even if it is only a worker's handwritten list or notes. Job aids are more cost-effective than most

Box 7-I—A Truck Driver Simulator

Shell International Petroleum Company Limited, London, has a large truck fleet, and wanted to reduce its annual accident rate. Shell's safety experts determined that a lack of defensive driving was the primary problem, rather than inadequate driver skill. Using interactive videodisc IVD), they developed a truck driver simulator that teaches defensive driving, including constant alertness and readiness to respond to potential hazards before a situation becomes dangerous.

The main objective of the simulation is to encourage defensive driving through a series of cause and effect situations. Shell accomplished this by constructing and videotaping 20 different road hazards based on visual clues (from a driver' s-eye view) of potential danger ahead. The hazards include slippery and dark roads, pedestrians and cyclists, distractions within the cab, and other common causes of accidents.

Because timing is critical to defensive driving, learners must act within a certain time period when they think a hazard situation is developing. Thus each clue incorporates three time periods: in time, late, and too late. When the learner reacts, the program stops the action and displays a list of possible responses to the situation (with the "too late" time period offering no positive choices). The outcomes vary from complete avoidance of danger to realistic crashes and embarrassing newspaper headlines. The driver rating (defensive, inattentive, dangerous) for each hazard depends on the combination of timing and action selected.

A replay option explains the clues that led to each hazard, with text and graphic overlays including a timeline indicating at what point each clue occurred. Other options include a pre-drive vehicle safety check and a practice drive during which learners are encouraged to experiment with various combinations of timing and action. After practice, learners may select a test drive, which contains seven hazards in a row. As in real driving, each hazard can be dealt with only once. The program gives the final score and rating at the end of the test drive. The courseware also includes a database of facts about the 20 hazards, which the learner can access at any time.

Shell International has not yet undertaken a formal evaluation of Defensive Driving's effectiveness. Anecdotal reports from drivers suggest, however, that it is improving the way they think about road hazards The clue sequence, in particular, appears to help drivers form a mental model of the development of road hazards and sharpen observation skills.

The U.S. military also uses driver simulators (e.g., the M-1 tank simulator). A truck driver simulator also is a test program for DVI (see discussion of digital videodisc). Simulators have a potentially wide application in driver training, where they would be safer for preliminary training, and could save fuel and vehicle wear-and-tear. They also could be used in driver's license testing, where they would provide consistency and decrease cost and enhance safety.

SOURCE: Deborah H. Blank, "Defensive Driving: Shell's Interactive Commitment to Safety," ***Instruction*** **Delivery Systems, vol. 4, No. 2, March/April 1990.**

Box 7-J—SIMNET: Networked Simulators in Military Training

A continuing problem in military training is providing enough hands -on practice in the operation and repair of equipment, including weapons, support vehicles, telecommunications gear, and logistics hardware. In many cases, it is too risky or expensive, or physically impossible to use the actual equipment for training. Consequently, the military has become a big advocate of simulators (see appendix).

Even simulators historically have been unable to provide hands-on training in team skills and group coordination, however. To be effective on and off the battlefield, soldiers and their commanders must be able to function as a unit. SIMNET is a research project initiated by the Defense Advanced Projects Research Agency (DARPA) to connect simulators via local and remote networks. In its current configuration, SIMNET consists of 250 networked simulators at 11 sites (7 in the United States and 4 in Europe). Equipment simulated includes Ml tanks, M2/3 Bradleys, fighter aircraft, helicopters, command/fire control elements, and a battalion operation center. Evaluation is of both the combat soldiers and their commanders. Preliminary data indicate that SIMNET significantly improves unit performance.

While any of these networked sites can "fight' any other, incompatibility among programming and equipment (e.g., operating speed) is a continuing problem. The installed base of military simulators uses a wide range of databases (e.g., for terrain imaging), communications protocols, and levels of hardware sophistication that are incompatible. Thus a tank that moves behind a building on its simulated terrain may still be in plain view on its opponents' screens. Similarly, the amount of data flowing through the satellite network led SIMNET to adopt relatively simplistic rules for updating screen images. These provide unrealistic positioning of high-speed objects (e.g., fighter aircraft). Finally, SIMNET accommodates the varying levels of visual fidelity in simulators through a lowest common denominator, which fails to use the full capability of the more sophisticated (and expensive) systems. These problems do not make for realistic battle simulations.

The services and their contractors are now developing standards for databases and communication protocols that will alleviate these problems. Target completion date is May 1991.

SIMNET pushes the state-of-the-art in technologies related to computer animation and 3D graphics as well as packet-switched networks.[1] It also presents new training opportunities, such as replaying the recorded performance of a unit to analyze mistakes. In addition, it opens up the possibility of "what if" experimentation in combat situations-something not really possible in field exercises.

SIMNET is having major repercussions for the nature of future military training. It also is likely to influence civilian training in any application requiring teamwork, especially when multiple sites are involved (e.g., disaster preparedness). It also could be useful for interpersonal skills training in areas such as management, sale, and customer service, although teleconferencing is more likely to be used for these applications in the near term.

---

[1]Packet-switching was developed for data communication between computers. Digital information is packaged into small pieces called packets, each containing information about the source and destination of the data and the relationship of that piece to the whole message. The packets are transmitted separately through the network, sometimes taking different paths depending on which ones are free at the moment. See U.S. Congress, Office of Technology Assessment, *Critical Connections: Communication for the Future*, OTA-CIT-407 (Washington DC: U.S. Government Printing Office, January 1990).

SOURCES: Greg Kearsley, "Instructional Technology and Worker Learning Needs," report prepared for the Office of Technology Assessment under contract L3-5615, February 1990; and W.A. Demers, "All Together Now," *Military Forum,* November/December *1989.*

formal training, often can be developed faster than an instructional program, are more timely in that they provide the training at the immediate point of need, are more easily updated than instruction, and often are more relevant to specific jobs. They also can aid in the transfer of training to job performance.[43]

Many of the most effective job aids do not require technological devices at all; well-designed print or graphic materials are often all that is required. For example, on an automobile production line, where torque requirements vary among components and models, a table printed in large type showing the needed torques might hang at the appropriate point

---

[43]Kurland, op. cit., footnote 13.

on the line. A similar table would be used at the quality control checkpoint. Such job aids do not differ much from old-fashioned maintenance manuals except in the attention that is given to their design and access.[44] Other examples of job aids include the checklist that flight crews use before a plane takes off, and computer keyboard templates that remind the operator which function keys do what.

Embedded Training

Embedded training is instruction that is an integral component of a product or system. In a computer, for example, it is easy to provide online training (help screens, tutorials) as part of the system (see box 7-K). Most other devices that use microchips now include diagnostic circuitry that speedily identifies any malfuction; some also describe how to repair it. Automated manufacturing systems also now include built-in training and documentation (e.g., the Martin Marietta and Apple factories discussed previously). DoD also is interested in embedded training, which has focused the interests of military R&D contractors on embedded systems, and may hasten their transfer to civilian technologies.[45]

The movement toward embedded training is being driven by a number of forces in contemporary technology, including the increasing capacity of microchips, their incorporation in more and more equipment, and the speed with which new technology is introduced. Equipment life is getting shorter. When a machine was expected to last 20 years or more, traditional training with a high initial cost was cost-effective. As the life expectancy of equipment has dropped to 5 years or less, it has become too costly to train workers in the traditional way every time a new machine is introduced. Embedded diagnostics and training reduce both the preservice training time and the onsite repair/maintenance time.[46]

Embedded training has many advantages over other forms of instruction. The most important is availability-training is always available when needed. Thus, embedded training is useful for applications where it is either impossible or not cost-effective to train everyone who uses apiece of technology about all of its operational characteristics. For example, office copy machines today often include graphic displays that show where a problem occurred (e.g., a paper jam) and list the steps needed to remedy it.

Second, embedded training is available at the work station and is focused on the worker's immediate needs for operation or repair. Third, it makes it possible to combine the sound instructional design principles of good formal off-the-job training with the best features of informal training (e.g., co-worker interaction, immediate opportunity to apply the results). Embedded training also simplifies the logistics of providing training to customers or employees because it is delivered along with the product or system.[47]

With embedding it also becomes possible to shift costs from employees to customers. One of the most visible examples is the automated teller machine. The next step is moving the teller function into the home via telephone and/or computer-a service now offered by many financial institutions. Indeed, as the technology of embedding improves, the skills needed by the end-user decrease to the point where vendors are now shifting the responsibility for installation and maintenance to the user.[48]

However, embedded training is difficult to design and many current efforts are not very successful. To be effective, the information must address the specific questions or problems that people might have when using or repairing equipment. A lot of empirical work with prototypes and typical users is needed to anticipate the full range of questions or problems that might arise. User-testing early in the design cycle is a relatively new concept in system development, and most engineers have not been trained in such data collection methods.[49] Also, if the training provided is too restrictive, it can inhibit

---

[44] Ibid.

[45] Kearsley, op. cit., footnote 1.

[46] Kurland, op. Cit., footnote 13.

[47] Kearsley, 0p. cit., footnote 1.

[48] Kurland, op. cit., footnote 13.

[49] Ibid.

Box 7-K—The Manpower Services Training System

In the early 1980s, Manpower, a temporary employment service for offices and factories, saw that with changes in technology it could no longer expect to find personnel who *were* able to use the full range of client equipment. Manpower searched unsuccessfully for an *existing training* system that would be time- efficient, cost-effective, and work for many people with widely varying backgrounds at dispersed locations. The company found the training programs and manuals supplied by equipment manufacturers too hard to understand. Moreover, it felt that most off-the-shelf training programs taught more than was needed to begin machine use. Overly ambitious programs might increase learners' fear of new technology, which were great enough already.

Instead, Manpower developed Skillware, a series of computer-based training programs to teach operators the hardware and software they will use on assignments. Skillware has modules that differ in difficulty (basic, advanced, and executive) and in application (special features, graphics, databases). It is personalized and contains humorous elements intended to help hold trainees' attention and reduce their fear of the equipment (see figure). Training may last from a few hours to 2 days depending on the module. Skillware is job-specific, teaching a temp only the skills that clients request. To achieve this, it uses scenarios; i.e., the trainee works for a fictitious company and has to complete a task for that company by the end of the course.

At a computer terminal, trainees proceed at their own pace through on- screen tutorials and instruction booklets (computer/software manuals written in clear language). Each tutorial/exercise segment can fit on a single screen and focuses on a basic operation (e.g., moving the cursor, printing a computer-edited document). A training administrator is available to answer questions, but Manpower prefers that trainees work themselves out of jams (as they might need to on assignment). At the end of training, the trainee is asked to compose a letter about the training program to Manpower's president; an acceptable letter is seen as a valid performance test. (Some letters have offered suggestions to improve training that Manpower has adopted.) After the training, each operator receives a "quick reference" manual (containing terms, functions, and replicas of tutorial screens) to take to the job.

Recently, Manpower initiated a skills assessment system for job applicants (including applicants for temporary light-industrial positions). As the company rejects few applicants, the system serves primarily to place people in appropriate positions. For office placement, Manpower uses a work-sample test to assess editing, proofreading, clerical, and word-processing skills and to determine applicants' training needs. The assessment system for light-industrial applicants includes performance tests to measure sorting and checking, tool-related assembly, printed circuit board and small-parts assembly, and coordinated rapid movement. Written tests assess aptitude for tasks such as inspection and logging production. (Manpower does not yet offer training to its light-industrial temporaries, but recognizes that the trend toward automated manufacturing could require such training soon.)

The company provides Skillware free to all employees, including its light-industrial temps. (A 2-day course costs Manpower $100 per trainee for equipment, material, and development.) The company feels Skillware is a powerful recruiting tool-people who know they can get free computer training may be more apt to sign up with Manpower than with another temporary agency. When not on assignment, office temporaries are encouraged to come to a Manpower office to learn another software program or familiarize themselves with new equipment.

The company has begun to train permanent workers at client organizations. For example, IBM hired Manpower to provide a training program for IBM's System/36 customers. In return for training those customers, Manpower gets access to pre-releases of IBM hardware and software so it can anticipate future needs in the temp market.

Manpower continues to invest in training research and development to stay on top of the ever-changing world of office hardware and software. (Currently the firm spends around $3 million annually, but it spent $15 million for R&D in the first 2 years of the Skillware project.) Manpower believes the success of its training and R&D efforts is reflected in its market success; in 1989, sales were $3 billion-double those of the nearest competitor.

workers' ability to use their intuitive knowledge and to foster innovation.[50]

Thus, good embedded training requires that instructional system design experts work with product design engineers. Traditionally, training materials are developed after the system or product is completed. The inclusion of training specialists as part of the design team often requires organizational changes and different skills in the training department. Finally, artificial intelligence techniques may be

[50]Institute for Research on Learning, *The Advancement of Learning,* undated pamphlet; John Seely Brown and Paul Duguid, "Design for Implementability," paper presented at the conference on Technology and the Future of Work, Palo Alto, CA, March 1990.

necessary to create embedded training programs that can pinpoint what the user wants to know.[51]

In time, the movement toward embedding could affect many aspects of workplace training. In theory, far less training would be needed prior to assignment to a specific task, reducing the cost of training. Moreover, embedded training occurs at the workstation, improving transfer of learning to work. The involvement of instructional systems experts in product design also improves the human factors aspects of equipment. Finally, fewer workers would be needed because equipment operators increasingly can also perform routine repairs and maintenance.

THE COST OF TECHNOLOGY-BASED) TRAINING

There are several elements in the cost of technology-based training. The easiest to fix are the purchase costs of hardware (e.g., PCs, IVD systems, satellite dishes) and off-the-shelf courseware. Additional costs may be incurred in adapting the courseware or retraining instructors. If off-the-shelf courseware is not available, custom courseware development costs also must be considered. If frequent updates are needed, they will add to the longer term costs. Other costs relate to the delivery setting (e.g., rewiring a classroom for teleconferencing, adding computer tables to switch from a lecture to a CBT format). Finally, the labor cost of delivery (time off work) must be considered. Table 7-5 shows the training budgets for various sized companies in 1989. These data suggest that the smallest companies spend less than $100 per employee on training while companies with more than 500 employees spend $100 to several hundred dollars per employee.

Classroom training often has a very low front-end cost. Most companies have a conference room or other area that can double as a classroom. Supporting hardware (blackboard, overhead projector, flipchart) and printed materials are relatively inexpensive and easy to obtain. Lab equipment usually can be scrounged from operating departments; class projects are even a way of saving repair and maintenance costs. The instructor often is a subject-matter expert from within the company or is hired on a contract basis. However, classroom training is consistently shown to be the most expensive in terms of the labor costs of delivery (time spent away from the work station) and travel to a central corporate classroom or a course offered by another organization. Costs rise dramatically for companies or agencies with offices throughout the Nation or around the world.

Table 7-6 compares the costs of other common technology-based training systems. All costs vary with the level of sophistication of the system and courseware. The number of participants also can affect direct costs (e.g., for satellite services). If a learning site needs to be rewired for satellite, teleconferencing, cable, or other services, these modifications will add substantially to the costs.[52]

Trade-offs between the convenience of off-the-shelf courseware versus the cost of programs tailored to specific needs also must be considered. Many training analysts argue that most good training has to be situation-specific and cannot be met with off-the-shelf or generic programs, no matter how good. Some floppy disks and erasable videodiscs can be updated or adapted to individual corporate needs with little effort; other programs cannot be altered easily or require remastering. Also, there is little independent evaluation of the claims for effectiveness of off-the-shelf programs.

Custom courseware development costs vary widely depending on the medium, program length, and, for CBT and IVD, level of interactivity and sophistication as well as the development tools used (e.g., authoring systems, supporting databases). A CBT courseware designer at Boeing Aerospace and Electronics estimates that he can design a 20-minute CBT course in about 4 hours (excluding any video or graphics work) using a relational subject-matter database. In contrast, the instructional design department at Stromberg-Carlson estimates that it takes them 300 hours to produce 1 hour of CBT compared with 30 hours to produce 1 hour of classroom instruction.[53] Estimates from consulting companies range from 50: 1 to 600:1 depending on the complexity of the course and its subject matter. The actual authoring may only take 15-20 percent of the

[51] Kearsley, op. cit., footnote 1.

[52] See ch. 3 and app. B of *Linking for Learning: A New Course for Education* provide detailed assessments Of the cost components of distance learning systems, OTA-SET-430 (Washington, DC: U.S. Government Printing Office, November 1989).

[53] Geber, op. cit., footnote 3.

Table 7-5—The Allocation of Corporate Training Budgets for Various Size Companies[a] (dollars)

	Outside expenditures								
Number of employees	Seminars/ conferences	Hardware	Outside services	Custom materials	Off-the-shelf materials	Total outside expenditures	Facilities/ overhead	Trainer salaries	Total budget
100-499	$11,258	$6,213	$4,419	$3,611	$4,153	$29,655	$9,093	$21,173	$59,921
500-999	16,911	11,502	8,726	8,359	8,340	53,838	27,207	42,854	123,899
1,000-2,499	30,321	23,676	29,027	13,129	14,834	110,987	62,471	146,996	320,454
2,500-9,999	125,180	89,805	52,487	54,541	56,852	378,864	124,318	1,000,515	1,503,697
10,000 or more ...	469,150	554,111	386,031	414,110	356,376	2,179,779	1,053,898	16,502,442	19,741,505

[a]The data in this table are derived from a survey that had a very low response rate. Thus they provide only a rough approximation of corporate training budgets. They are included here as an indication of how the budgets of responding companies are divided among various training categories.

SOURCE: "Training Magazine Industry Report, 1989," *Training: The Magazine of Human Resources Development*, vol. 26, No. 10, October 1989, p. 44.

Table 7-6-Technology-Based Training Costs

Medium	Equipment	Hardware	off-the-shelf courseware
Television	TV set	$250-$3,000	$0-cable or other subscription cost
	Satellite dish	$800-$10,000	$200-$5,000
Videotape	VCR	$150-$500	$100-$10,000 purchase $50-$200 rental
	Video camera	$700-$2,000	
CBT	PC	$750-$10,000	$50-$10,000
	Workstation	$10,000-$50,000	
	Authoring system	$100-$5,000	
IVD	Level I[a]	$400-$1,000	$50-$5,000
	Level II	$1,000-$2,000	$300-$5,000
	Level III	$5,000-$10,000	$500-12,000
	Authoring system	$500-$8,000	
Digital video	DVI	$2,000-$21,000	NA
	CD-1	$3,000	NA

ABBREVIATIONS: CBT. computer-based training; CD-1 = compact-disc interactive; DVI = digital video interactive; IVD = interactive videodisc; NA. not available; PC= personal computer; VCR = videocassette recorder.

[a]In this context, "level" refers to the type and capabilities of the hardware.

SOURCE: Office of Technology Assessment, 1990.

development time and initial design and testing/ quality assurance the remainder.

IVD course development costs also vary with the sources for the video/audio/graphic components. Some IVDs and CD-ROMs available today are "resource discs" with still frames, audio, or video for various situations. The purchase price may include royalty costs. If, however, original film and sound must be recorded, the production cost will drive up the price. Total costs for a l-hour course that uses available resources may be as low as $4,000, while a 5-hour course that requires filming, sound recording, and computer programming may cost several hundred thousand dollars.

Several innovations promise to reduce the cost of technology-based training. Authoring systems and other instructional design tools, resource discs, and relational subject-matter databases substantially reduce the development time and labor costs. Equipment and courseware leasing options reduce the front-end costs for training that is delivered infrequently. Some professional associations are promoting the concept of 'shareware" for training materials. Learning centers are being established that provide services such as satellite links and CBT and IVD training stations, with accompanying courseware.

THE EFFECTIVENESS OF TRAINING TECHNOLOGIES

The concept of "good" training has two distinct lines of thought that are only now beginning to merge. The first is adult learning theory, which has engendered a wide range of approaches to training, many of which have undergone little empirical evaluation. The second is corporate productivity—training is effective if it appears to improve job performance and reduce costs. While little empirical research has been done in this area, the focus on productivity gains did promote the use of standard instructional development principles to ensure that training was specific and relevant. This section evaluates the available data comparing technology-based training with conventional methods. The following section discusses adult learning theory and instructional systems design.

Few companies have the time or resources to compare the cost-effectiveness of different training delivery systems. Many training delivery decisions are made in an atmosphere of 'crisis management' and, while not arbitrary, are more often based on a combination of the available training funds and the training manager's experience with a particular system than on a measured consideration of short- and long-term benefits. Evaluation of training benefits and costs is usually informal and cursory-often based on word-of-mouth feedback from participants and their supervisors.[54]

Most training managers are not themselves trained in benefit-cost analysis. Even if they understand the theory, there are practical obstacles to its application, including the difficulty of quantifying training benefits, the subjectivity and questionable nature of the assumptions underlying such analysis, the inability to separate the influence of training from other factors that might improve performance, and the time and financial resources needed for analysis. Benefit-cost analysis also is not usually a management priority, either because it is not seen as valuable or because training itself is not an integral part of the corporate operating strategy.[55]

The lack of benefit-cost analysis can mean that training departments can hide ineffective training—whether a bad program or course, or training that simply does not transfer to the workplace. For good training, however, benefit-cost analysis can elevate training to a line item that improves productivity and profits rather than a staff function that spends money. Thus, benefit-cost analysis might justify a separate corporate training department and contribute to making training part of a company's underlying business philosophy.[56] Increasingly, companies are shifting budget responsibility for training to operating managers to promote cost-effectiveness. This places greater demands on trainers to keep the operating managers informed about developments in instructional technology and available courseware.

Ironically, even when benefit-cost data are available, they may have little influence on decisions to use technology-based training approaches, which are often made on entirely different grounds. Sometimes the rationale for using training technology is for the training manager or corporation to appear to be on the "leading edge" and thus attract positive media attention. Another rationale is convenience (e.g., adopting CBT because the computer terminals are already in place).[57] On the other side, the potential long-term effectiveness may be overshadowed by front-end hardware or courseware costs (e.g., IVD).

When cost-effectiveness evaluations of technology-based training are conducted, they often compare a subject taught via conventional classroom instruction with the same subject delivered via technology. This is an oversimplification for three reasons. First, they may reflect the simplistic view of technology as hardware, and thus ignore variables such as the quality of the software or courseware or the skill of the instructor. Second, technology-based training usually requires a change in teaching strategy and media and often involves a shift in course content and approach as well as the delivery setting. Third, these comparative studies assume there is a simple dichotomy between classroom and technology-based instruction. But classrooms often use a range of technologies, and technology-based instruction may be delivered in a classroom setting. A typical training course involves several types of instructional activities, some of which are more suited to the use of technology and some of which require lecture or discussion.[58]

Yet thousands of comparative studies have been conducted, especially for CBT, IVD, and simulators. Despite any oversimplifications that may be inherent in the study design, the study conclusions have been corroborated with years of corporate, military, and government experience with technology-based training.

Table 7-1 summarizes some of the potential benefits from various types of instructional technology. None of these will occur automatically; they require the right combination of instructional skills and courseware design with training appropriate for the task being learned. (Similarly, the potential disadvantages listed in the table depend on a wide range of variables.) Figure 7-4 illustrates ASTD's survey data on the cost-effectiveness of three training technologies.

One of the most consistent findings about the cost-effectiveness of good technology-based instruction is that training duration can be reduced

[54] Cynthia A. Lombardo, "Do the Benefits of Training Justify the Costs?" *Training & Development Journal*, vol. 43, No. 12, December 1989, pp. 60-64.

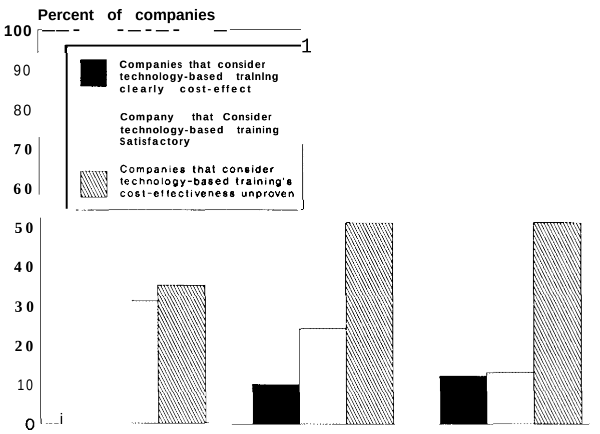
[55] Ibid.

[56] Ibid.

[57] Kearsley, op. cit., footnote 1.

[58] Ibid.

Figure 7-4-Reported Cost-Effectiveness of Training Technology



SOURCE: Based on American Society for Training and Development survey of 157 executives from Fortune 500 private firms with $500 million + in sales.

30-40 percent relative to traditional classroom lectures. This reduction appears to occur because of the design and delivery elements of technology-based training (adaptable to individual learning styles, self-paced, more private; see boxes 7-L and 7-M). This reduction in training time translates to large cost savings in less time away from the job and often lower travel costs. Organizations also can deliver more training over a given period.[59]

The best technology-based training also shows increased achievement in terms of test results, retention, and/or job performance (although the latter is difficult to measure). When coupled with computer-managed instruction, such training can provide automatic collection of data on student performance and help identify training problems. Moreover, many students report that they find technology-based training more interesting and enjoyable than classroom lectures. Students also have less fear of giving a wrong answer than in a group situation. Because the courseware is delivered in the same way each time, its quality is more consistent and reliable than classroom instruction. Fluctuations in the number of trainees and their backgrounds can be accommodated more readily. In most cases, the training also is available when and where the employee needs it without waiting for travel or course scheduling. This also improves access for the disabled. Finally, trainees can learn and practice more types of procedures without downtime or damage to real equipment, and without safety concerns on dangerous equipment (see box 7-1).[60]

The appropriateness of the training technology to the task being learned is an important element of effectiveness. Most training professionals agree that high-tech delivery systems are best suited to technical skills. Teaching someone the series of steps in processing an insurance claim or assembling equipment is a good application for CBT or IVD. Most trainers also agree that traditional settings such as classrooms and workshops are needed for imparting interpersonal skills, management training, and corporate culture building. Yet high-tech systems are beginning to make inroads here also (see box7-and the discussion of performance support systems, below), and their use probably will increase as artificial intelligence techniques make video simulations of personal interactions more realistic. The delivery setting also can influence technology effectiveness (see box 7-N).

Most of the evidence about the cost-effectiveness of training technology comes from the armed services. A recent Institute for Defense Analyses survey examined data from 100 studies on the cost-effectiveness of CBT, flight simulators, and maintenance simulators, with most studies showing that technology-based training saves time and results in higher achievement.[61] A survey of 31 studies of IVD training (15 military, 3 industrial, 13 higher education) concluded that IVD was more effective than conventional instruction in almost all cases. The more interactive features used, the more effective the IVD) training appeared to be (see box 1-C in ch. 1).[62]

Stromberg-Carlson, a Florida telecommunications company, devised an IVD simulation of new telephone switching equipment it produces and compared the simulation with training on the actual equipment. The IVD program was faster because more students could use it at any given time, and the

[59] Ibid.

[60] Ibid.

[61] J. Orlansky, "The Productivity of Training," J. Zeidner (ed.), *Human Productivity Enhancement* (New York, NY: Praeger, 19S6), VOL L

[62] J.D. Fletcher, "Report on the Potential of Interactive Videodisc Technology for Defense-and Education" (Alexandria, VA: Institute for Defense Analyses, 1989).

Box 7-L-The Effectiveness of Interactive Videodisc in Training

Although its use has grown slowly, IVD is becoming an increasingly common training technology. Evaluations-when conducted-seem to be uniformly positive. Some examples are:

- *Goodyear Tire & Rubber* compared a videodisc training program for mechanics on using an oscilloscope and multimeter with the same training via videotape or classroom. In actual job performance tests after training, the IVD approach produced the best results. Furthermore, trainees indicated a preference for the IVD course.
- ***McDonnell Aircraft Company in*** conjunction with Digital Equipment Corp. developed a videodisc training program for computer-aided design (CAD). The program cut training time for this course from 12 hours to less than 8 hours for all trainees, decreased the cost per student hour, reduced teaching loads, and resulted in better retention of the material.
- ***IBM*** conducted research at its Corporate Management Development Center comparing three ways of using IVD (instructor-led, small groups, and self-study) with classroom instruction for an employee relations course. Learning gains scores and mastery levels in the IVD approaches were better than classroom instruction alone.
- ***GTE of California*** compared IVD with classroom instruction in training technicians to troubleshoot a statewide data network. The IVD training was superior in retention and was well liked by the employees.

SOURCE: Greg Kearsley, "Instructional Technology and Worker Learning Needs," report prepared for the Office of Technology Assessment under contract L3-5615, February 1990.

retention rate was higher because students had more access time.[63]

INSTRUCTIONAL DESIGN

Worker training's cost-effectiveness is always an issue. Some training fails to impart the appropriate skill for the job, misses some aspects of the skill, includes irrelevant information, or does not match the trainees' backgrounds and learning styles. This can mean ineffective training for a cost that is higher than necessary. To help training become relevant, complete, lean, and suitable, a set of principles and procedures has been devised to guide instructional development. First devised in the mid-1950s, these principles have evolved with changes in adult learning theory, and now are used widely throughout industry, government, and the military. In recent years, these principles and procedures have become partially automated with computer programs for designing and authoring instruction.

Adult Learning

In 1973, Malcolm Knowles, then a professor at Boston University, argued that the traditional pedagogical approach to teaching children is inappropriate for teaching adults in most situations.[64] He introduced a new approach—termed *andragogy*-that was more flexible, participative, experience-based, and problem-centered.[65] While it has been challenged on several grounds, andragogy's most important contribution probably is that it created a greater sensitivity to the needs and interests of the learner.

Today, training developers use needs analysis (see discussion of instructional development, below) to determine the best approach to imparting a task. For some training situations, pedagogical methods make the most sense-for extremely technical topics, for example, or for tasks that follow rigid performance steps, or for subjects entirely new to learners.[66]

At the same time, good training programs increasingly recognize the tremendous diversity among adults, including the wide range of ages, attitudes, educational backgrounds, learning styles, and instructional goals and settings. For example, adults with the most formal schooling are more likely to

[63] Geber, op. cit., footnote 3.

[64] Malcolm Knowles, *The Adult Learner: A Neglected Species*, (Houston, TX: Gulf Pub. Co., 1973).

[65] Dale Feuer and Beverly Geber, "U'h-oh. . . . Second Thoughts about Adult Learning Theory," *Training*, vol. 25, No. 12, December 1988, pp. 31-39.

[66] Ibid.

Box 7-M—A Comparison of IVD Delivery Settings

Historically, research comparing group and individual learning for lecture/lab has shown that the group settings are superior in promoting achievement and productivity. Studies that compared CBT using pairs and individuals found similar results. Only one such study has been performed with IVD. It compared group, paired, and individual instruction on the same courseware, with the pairs yielding the highest achievement, followed by groups and then individuals.

The predominant instructional setting with IVD has been individual instruction. Its major advantages include self-pacing to accommodate individual learning rates, knowledge levels, and training needs; and flexibility in scheduling and the physical setting. Using IVD in pairs also allows self-pacing (if the trainee pair was chosen properly), is only slightly less flexible in scheduling, plus it cuts collective learning time in half, facilitates learning through discussion, and builds rapport among trainees, which can encourage networking between departments and can resolve multicultural differences. Larger group instructional settings for IVD are gaining popularity. They provide: an opportunity to tailor generic courseware to a company's needs, in that the instructor can add to or modify the IVD to create discussions or skip sections; the dynamics of group interaction and debate; the popularity of group socialization (e.g., coffee breaks); and, in some cases, more cost-effective training. However, scheduling becomes less flexible, self-pacing usually is sacrificed, and there is more fear of giving wrong answers.

Each training situation will be different, however. Companies need to conduct trials with different delivery settings to determine which is best for their training needs. The advantages of paired or group learning may be insufficient to overcome the costs of multiple training stations or scheduling conflicts.

SOURCES: Richard P. Lookatch, "Options for Interactive Video," *Training & Development Journal*, December, 1989; J. Vadas, paper presented at Sixth Conference on Interactive Videodisc in Education and Training.

feel comfortable in structured classes and lectures.[67] Many trainees do not want to examine options and decide for themselves how to perform a task; they may consider it a waste of time when the instructor could tell them what to do and they could get back to work and do it. Similarly, some adults enjoy andragogical activities such as group role playing, while others find it silly or are intimidated by the situation. Finally, some people learn best by listening, some through group discussion, some by reading, others through visual cues, and still others through experiencing and practicing.

Adult learning theory has stimulated much debate over the last 20 years. Yet there is little basic research or evaluation of different approaches to applying the research in training. Despite the enormous sums spent on education and training, and despite the shortcomings evident in both systems, applied learning research has never been well supported except by DoD. Much of the current focus is on how to fix schooling. Yet the rapid pace of change in technology and work means what people need to learn is in constant flux. To promote more flexible and effective learning, more research on adult learning and how the results of that research can best be applied in the workplace is needed.[68]

There are several different areas that need further exploration. For example, more research is needed about the different combinations of learning approaches most likely to help people learn on the job (e.g., ways to combine formal and informal instruction, the roles of co-worker guidance and repeated practice). The apprenticeship model, for example, can promote flexible, powerful reasoning that transfers to other situations. Embedded training systems can be designed that take advantage of equipment operators' intuitive skills while helping them develop a deeper understanding of the processes involved.[69] Performance support systems have the potential to provide structured on-the-job training in a wide range of situations.

Instructional Systems Development[70]

Based on the current understanding of adult learning, a model or procedure for instructional systems development (ISD) has evolved that can

[67] Ibid.

[68] Institute for Research on Learning, op. cit., footnote 50.

[69] Ibid.

[70] Unless otherwise noted, the material in this section is drawn from Michael De Bloois, Interactive Training Seminar, Alexandria, Virginia, November 1989, and Eagle Technology, Inc., personal communication to OTA.

contribute to more effective training. The five basic stages of the ISD process are: analysis, design, development, implementation, and evaluation (see figure 7-l). This model is now followed in the military, by many large corporations' training departments, and by many designers of custom training programs. Instructional systems development also is offered as a degree program or included in the human resource development curriculum at some universities (the ASTD database shows 2 undergraduate ISD degree programs, 27 masters' programs, 13 PhD, and 8 cetificates). However, many human resource development personnel or subject matter experts assigned training responsibilities have not been exposed to ISD. Also, ISD principles rarely enter into training decisions made in a crisis management atmosphere (as many such decisions are), or in informal on-the-job training (the kind most workers receive). Moreover, while ISD can save money in the long run, the upfront costs can be considerable.

The first stage of ISD, analysis, helps corporate trainers (and managers) define training needs more precisely (or determine whether training is the appropriate solution to the problem) by describing the tasks or skills to be imparted and developing a trainee profile. This analysis contributes to the overall design of the training project, including the medium (e.g., lecture, videotape, computer, IVD) most appropriate for the training. The design decisions are then developed into a combination of courseware and hardware (or a decision to purchase off-the-shelf courseware).

In theory, before full-scale implementation, ISD also includes some field testing-formative evaluation-of the behavior of people using the training package. Revisions can then be made before the finished product is produced for the training site. Ideally, the training program also is evaluated (and revised as needed) after implementation to determine how well the training transfers to employee performance, both at the end of training and on the job. In practice, however, few companies devote substantial efforts to evaluation.

Depending on the type of training package being prepared and the resources available, ISD may involve a team of experts or one or two people. For an involved IVD simulation, a team might include instructional designers, subject matter experts, computer programmers or video producers, and writers. On the other hand, a simple CBT package (e.g., how to fill out a corporation's forms) now can be produced by training personnel well-versed in ISD principles working with instructional design tools, resource discs, and a good authoring system.

There are several issues surrounding the ISD process. First, many corporate trainers are administrators, not designers. They may fail to determine whether off-the-shelf courseware was developed following ISD principles before they purchase it. Next, development of a good, comprehensive training program can cost hundreds to thousands of dollars. Task analysis, trainee profiles, and evaluation are especially costly, and companies often bypass or abbreviate them in order to save money. Yet these are key steps in the production of good training materials.

Establishing the medium also is critical for quality and cost considerations. A well-designed videotape or lecture (with supporting visuals or other tools) may be all that is really needed to impart the information, but translating that information to a computer program might save trainee time away from the worksite. On the other hand, the computer program might cost too much more to develop and implement. Some companies have chosen CBT or IVD as the medium because it is the leading edge without considering whether the medium is appropriate to, or its cost justified by, the task. They frequently are dissatisfied with the training results.

Automating Instructional Development

Training programs are generally hand-crafted and relatively labor intensive. Until recently, quality of the programs was almost entirely dependent on the developers' skill and experience. Now, however, software tools are becoming available to aid in training design. These include both instructional design and authoring tools.

These tools can facilitate the development and implementation of cost-effective training materials. The tools promise to be a major area of research and commercial activity within the next 5-10 years. Authoring systems already are established as an important category of software tools for training departments. Work on automated instructional development systems that cover all aspects of analysis, design, and evaluation is in its nascency. The application of expert systems to instructional development also is at an early stage but is likely to catch on quickly.

The overall effect of these tools will be to make it easier and faster to develop cost-effective training programs. Less expertise (either ISD, computer programming, and/or subject-matter) will be needed to create high quality training materials.

Instructional Design Tools

Instructional design tools are software packages that help designers in the analysis, design, and early development stages of ISD-everything up to authoring. The software also may provide project management capabilities for the ISD process. These automated instructional development systems are new (only a few are available commercially) and it is difficult to generalize about their features. Because many of them were developed for military projects, they often are linked to military design specifications and integrated logistics support requirements.[71] The key parameters to look for in such a system include the amount and type of built-in expertise, whether a system is advisory or operational, the skill needed to use it, the number of tasks it performs, the types of training technology it supports, its flexibility, and the hardware platform it requires.[72]

The amount and type of expertise built into the software ranges from basic online help systems to elaborate programs using artificial intelligence. How much expertise is required depends on the type of training package being developed and on the designer's skill. Some software includes a variable amount of expertise that can be accessed (turned up or down) as needed. Software maybe targeted either to ISD experts or subject matter experts. Some packages are advisory only; they provide checklists, flowcharts, templates, and other job aids for the designer. Others actually do the production based on the data entered (e.g., they perform the task analysis). The number of tasks the software performs also varies. Some programs do only one step, some do several. Those that include the entire process are still in the development stage. The software may be generic, in that it applies to all types of training technology, or it may be specific to CBT, IVD or large machine simulators (ships, planes, tanks). Finally, they may run on anything from a PC to a large mainframe.[73]

Instructional design tools have the potential to improve the productivity of training developers in many ways. By automating mechanical tasks such as sorting information or drawing charts, developers save considerable time. Easily accessible databases also speed up the development process. As job aids, such tools can compensate for a developer's lack of either ISD or subject matter expertise and can help maintain consistency in the quality of training programs. Combined with project management software and electronic mail, these tools can improve project tracking.[74]

To date, however, most of these systems were designed as part of research projects to investigate how automated tools could improve the quality or efficiency of training development. The research merely demonstrated that working systems can be built. No studies have been done yet that compare training packages developed with instructional design tools with those prepared manually, either in terms of quality or time/cost savings. Moreover, development of these tools has been on a path separate from the development of authoring systems, which focus primarily on CBT and IVD. The front-end results of instructional design tools do not yet feed directly into scripting and authoring.[75]

A special category of instructional design tools is available for expert systems and intelligent tutors. Indeed, one of the more important applications of expert systems in training may be to provide intelligent job aids for instructional system design. Some programs provide "shells" for the creation of expert systems or intelligent tutors. These shells are prewritten programs that help a designer develop an expert system/tutor without programming skills. As with other design tools, the system suggests organizational or teaching strategies and/or makes recommendations about design approaches based on the

[71] Kearsley, op. cit., footnote 1.

[72] Virginia Anderson, "An Overview of Software Tools for Instructional Design," paper presented at 8th conference on Interactive Instruction Delivery, Orlando, FL, February 1990.

[73] Ibid.

[74] Ibid, and Kearsley, op.cit., footnote 1.

[75] Kearsley, op. cit., footnote 1.

content information provided. They also may provide advice about evaluation and course administration.[76]

Expert system/tutor shells also face the general problem of the current lack of knowledge about how to design effective training materials. Also, there have not yet been any comparative evaluation studies. Conceptually, such shells are easier to construct than ISD tools because all the designer needs is several experts who can consistently perform a task with good results.[77] However, translating that knowledge into rules and programming it may still be difficult and time consuming.

Authoring Tools

Authoring tools use high-level language programming to create interactive computer-based courseware (either CBT or IVD). Authoring languages are either standard computer languages (e.g., BASIC, C) or a language designed for creating instructional material; they require skill in programming. Authoring systems are programs that help people write other programs. The systems allow an instructional designer or subject matter expert with no programming background to create computer-based courseware.[78]

Authoring systems followed quickly on the heels of the PC. In 1985, there were around 12 authoring systems; the number expanded to over 100 and then shrank to around 80 today.[79] Most of them support interactive video and provide computer-managed instruction. For some of the more popular systems, there are also user groups and consultants available for training or contractual development. Several firms are now adapting authoring systems for digital videodisc (see discussion of future technologies).[80]

Authoring systems vary widely in their sophistication and capabilities. Most present menus that allow the developer to choose input from a variety of sources (databases and resource discs of video, audio, and computer graphics), specify types of interactivity, select features such as windows and overlays, and choose presentation styles (such as video wipes or other transitions). Once these are specified, the system automatically generates a program that should be bug-free. Eliminating the need for programming and debugging can reduce development time substantially .81 Authoring systems do vary in their flexibility-the extent to which the user can shape the process. Menu-driven systems often are easy to use and learn, but they can restrict flexibility. Others are transparent in the sense that a programmer can change code.[82]

Authoring systems have evolved to the point that programming is no longer a major consideration in the development of computer-based instructional materials (other than which system to use). However, knowledge of ISD principles usually is still necessary. Unless they are trained in the design of interactive instruction, most training developers do not have a clue which options to select to make effective training materials. Eventually, automated instructional design tools will increase productivity in this area, but the developer's skill will still be critical. Another problem is the lack of hardware standards for operating systems and for peripherals such as videodisc players, so that authoring software would work with all types of devices. Standards for interfaces (e.g., CD-ROM drives) also are needed.[83]

FUTURE TRENDS FOR TRAINING TECHNOLOGIES

The rate of increase in the adoption of technology-based training is accelerating. By 1993, 93 percent of the executives from large firms polled by ASTD project 'some' or ''substantial' CBT applications, with substantial use more than doubling over 3 years, from a current 12 percent to more than 29 percent (see figure 7-5). IVD applications are projected to increase to 71 percent use, with substantial use growing from 7 percent in 1989 to 15

76Clay Carr, ''Expert Systems: What Do They Mean for Training'?" *Training,* vol. 26, No. 12, December 1989, pp. 41-48.

77Kearsley, op. cit., footnote 1.

78 Ibid.

79CEIT Systems, Inc., personal communication to OTA.

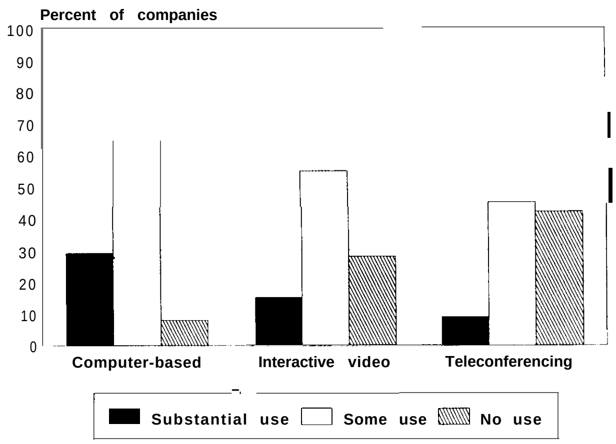
80''Authoring System Now Available for DVI Technology,'' *Intel Interactivities,* vol. 1, No. 3, winter 1989, p. 1.

81Kearsley, op. cit., footnote 1.

82Pinnacle Courseware Inc., personal communication to OTA.

83CEIT Systems, he., personal communication to OTA.

Figure 7-5-Projected Use of Training Technology, 1990-92



SOURCE: Based on American Society for Training and Development survey of 157 executives from Fortune 500 private firms with $500 million+ in sales.

percent in 1992. The executives project teleconferencing to increase to 54 percent by 1992.

At IBM, technology was used to deliver no more than 5 percent of the company's education in the early 1980s. At the beginning of 1990, training technology use had increased to 30 percent. Moreover, IBM adopted technological delivery media at a much faster rate from 1985 to 1990 than during 1980-85. IBM projects that by the end of the 1990s about 60 percent of the company's training will be delivered outside the traditional classroom using some form of technology. Northern Telecom Inc. also is moving rapidly toward technology-based training. Although 90 percent of its training still takes place in classrooms, as recently as 5 years ago that figure was 100 percent. The corporate training director projects that the rate of shift will increase rapidly, with ultimate plans to move toward the performance support system concept (see below).[84]

Several factors explain the more rapid shift toward technology-based training. First is hardware and software maturity and the availability and lower cost of off-the-shelf programs. An installed base of training technology platforms (e.g., computer terminals, satellite dishes, VCRs) makes it difficult *not* to use technology-based training. The entry of more computer-literate students into the workplace also will spur the growth of technology-based training. Finally, the limitations of most classroom training in terms of retention and transfer to job performance will lead managers to be more open to technology-based approaches.[85]

Many technological advances that are or could be available in the near future could spur this shift and greatly affect worker training of all types. Almost all of the advances use hardware, software, and concepts that exist now but are not yet used for instructional purposes or that will be used in radically new ways. Advances in storage, speed, and peripherals will make computers much more accessible for training. Software improvements will result in improved courseware. Electronic classrooms and digital networks will make multimedia training available anywhere at any time. Longer term advances will radically alter the way people interact with computers and provide an entirely new environment for simulations.

These changes will allow more learning on demand-usually at the normal workstation but increasingly in the field or at home-as well as more training that is controlled by the learner, more embedded training, and multimedia training is responsive to the individual trainee's learning style and pace. In the long term, these developments also could profoundly change the way many people work (e.g., by eliminating the need for a fixed or regular worksite in service industries) as well as the way they learn. Training would become even more integral to work and not separate from it.

Computer Technology

Advances in computer technology should greatly increase its utility for training. Options currently requiring a host of equipment may be incorporated in one unit. This integration will facilitate embedded training and performance support systems. Low-cost, easily usable optical character readers will increase access to information resources, particularly in rapidly developing fields. The storage capacity of future PCs will be enormous based on some form of optical disk such as erasable CD-ROM. Cellular modems will allow users access to electronic message systems and online databases without the need for a phone jack. An integral fax will provide hard copy. Built-in television reception

[84] Geber, *op. cit.*, footnote 3.

[85] Ibid.

will give access to broadcast services.[86] Voice synthesis will allow access for the disabled and reading deficient and will enable workers of all types to receive instructions without taking their eyes away from their work. Over the longer term, speech recognition could reduce the time and effort needed to learn to operate complex machines or software systems, and enable anyone to generate multimedia programs without a keyboard, mouse, or touch-screen.[87] Voice recognition systems already are used in data collection to enable personnel not trained in computers to work effectively in a computerized environment. In automobile quality control, for example, voice recognition has proven faster than manual data input, and allows the inspector's hands to remain free for tactile tasks (e.g., feeling paint scratches) .88

The evolution of personal computers has a number of implications for training. First, the projected increase in the use of computers in the workplace and at home will make it unnecessary to buy them specifically for training (except for electronic classrooms). The increasing portability of computers will facilitate embedded training, performance support systems, and just-in-time training-putting the means to pull information into the workplace at the time and in the form it is needed. With the evolution of multimedia workstations, computer and videodisc training will accommodate individual learning styles more easily.

Even though personal workstations will eliminate many of the current problems associated with CBT hardware, there will still be compatibility and quality issues. Various operating systems will have differing capabilities and will run only particular types of courseware. Some displays will look better than others, some machines will access/display information more quickly, some machines will sound better than others. This range in performance characteristics usually will be determined by price, and access to the most advanced CBT will be limited by the training budget.

Software

Software developments that axe especially promising for training include hypertext and hypermedia systems that enable the construction and use of relational databases, and applications of artificial intelligence to learning. Automation of instructional systems design and improved authoring systems (discussed above) also show great promise.

Hypermedia

Hypertext or hypermedia (if it's multimedia) is the term for a new method for organizing online databases that allows users to pursue connections among different items of information, rather than being confined by a hierarchical structure such as a menu system. The authors link information (documents, graphics, or audio or video sequences), create paths through a body of related material, annotate existing texts, and create notes that point readers to either bibliographic data or another referenced text. Users also can make notes and add annotations or create their own links and paths. Systems that support multiple users allow researchers, instructors, and learners to communicate and collaborate within the context of a database.[89]

Emerging hypermedia systems will include more sophisticated navigational tools. These might show what links a reader followed to get to a document, which would facilitate incorporation of an intelligent tutor or computer-managed instruction system. Filtering would allow users to bypass links and concentrate only on those of particular interest. Alternatively, hot links would force the user down a particular path.[90]

Hypermedia presents a new paradigm for sharing information in an integrated fashion. Once instructional designers become familiar with its capabilities, hypermedia is likely to have wide-ranging impacts on courseware. To date, most instructional uses have been in education, but hypertext and hypermedia are beginning to be applied to embedded training and performance support systems. They will be less useful in applications where the task to

[86] Kearsley, op. Cit., footnote 1.

[87] Kurland, op. cit., footnote 13.

[88] John Martin, "Speak Up for Quality," *Manufacturing Engineering*, vol.103, No.10, October 1989, pp. 67-68.

[89] Nicole Yankelovich et al, "Issues in Designing a Hypermedia Document System," Sueann Ambron and Kristina Hooper (eds.), *Interactive Multimedia* (Redmond, WA: Microsoft Press, 1988).

[90] Ibid.

be learned is highly structured and needs to be learned quickly.[91]

Artificial Intelligence

Research has been conducted for many years on the application of artificial intelligence (AI) techniques to instructional material design. AI typically focuses either on intelligent tutors or expert systems. Intelligent tutors are computer-based instruction programs with a large amount of background information. They include associative networks, the capability to draw inferences from programmed rules, and the ability to build models of students' behavior based on their interaction with the program in order to diagnose misconceptions and assess learning. Intelligent tutors and have the potential in time to provide much more effective learning tools.[92]

Expert systems are programs that incorporate the rules, facts, concepts, procedures, calculations, and rules of thumb used by experts in a field. This knowledge base is then applied to generate conclusions about the learner's input (see box 7-N). Expert systems also can ask questions about an equipment malfunction and diagnose the problem. In real-time systems (e.g., in manufacturing or military settings), data come from sensors rather than answers to questions. When applied to training, expert systems can be used to help students understand the factors involved in making decisions or judgments. Alternatively, expert systems can be used as sophisticated job aids that reduce or eliminate the need for training on a specific task.[93]

Few intelligent tutors have actually been used in training. Developing tutors takes an enormous amount of time and expertise in artificial intelligence. Despite the amount of research in this area (mostly funded by DoD), there are many fundamental issues in adult learning and cognitive theory that need to be resolved before it is clear how to design intelligent tutors that really work.[94]

In contrast, expert systems are much faster to develop and do not require AI experience to use. The current generation of authoring tools for building expert systems is relatively easy to use and inexpensive. Instructors could even have trainees develop simple expert systems to help them learn a subject while producing a job aid that will carryover into the work environment.[95]

Performance Support Systems

A performance support system is an advanced type of computerized job aid. It has more information available than CBT, and the user controls access to the learning or information rather than the machine.[96] Indeed, performance support systems provide structured on-the-job training that could substitute for some kinds of formal training.

Performance support systems (PSS) are a new concept and few exist; thus generalizations are difficult. Examples are provided below to illustrate some of the features and uses to date. A PSS might incorporate any combination of text, graphics, audio, still video, applications software to perform specific job tasks, databases, expert systems, interactive training programs, assessment systems, and feedback and monitoring systems. With the development of digital technology, full-motion video also will be possible.[97]

Two major recent developments have promoted performance support systems. First, storage technology for PCs and portables has advanced. Second, innovations such as hypermedia gave rise to the crucial underpinning of a PSS—the relational database which ties all of the above elements together.[98]

Today, a PSS often is not initiated by the training department. It might begin in customer service, with a need for a relational database that makes large amounts of information easily accessible to telephone customer service representatives. The same information is then found valuable in sales, and

[91] Kearsley, op. cit., footnote 1.

[92] Ibid.

[93] Ibid.

[94] Ibid.

[95] Ibid.

[96] Geber, op. cit., footnote 3.

[97] Ibid.

[98] Ibid.

[99] Ibid.

31-463 - 90 - 8 : QL 3

Box 7N-The Flight Plan Critic

The Flight Plan Critic is an instructional expert system developed jointly by WICAT Systems, the University of North Dakota, and Northwest Airlines to help aviation students learn how to plan a cross-country flight. The Flight Plan Critic was developed using the WISE authoring system linked to OPS5—an expert system development language-and runs on a WICAT work station. It represents one of the first instructional expert systems to be used in a real training setting with a commercially available CBT system.

The student begins by developing a flight plan using a variety of information about the aircraft and its load, maps, and weather conditions. All the students' steps used in calculations and decisions are recorded. When the student completes the flight plan and 'files' it, the plan is analyzed by an expert system for correctness. If mistakes are found, the expert system diagnoses the source of the error and provides feedback to the student including prescriptions for improving performance.

Development of The Flight Plan Critic presented several CBT design challenges. Extracting enough information from student responses to diagnose problems was difficult and required the adoption of a "mixed initiative" approach in which the expert system would present its advice but let the student decide what to do with it. Determiningg when to give feedback and what kind also presented design problems. These stem from the inadequacies in our current understanding of how learning occurs.

The Flight Plan Critic is now being tested with aviation students and fine-tuned based on the test data It demonstrates that existing authoring tools can be extended to accommodate expert system and intelligent tutor capabilities. It also illustrates that development of new forms of interactive instruction will require substantial research about learning and teaching.

SOURCE: Andrew S. Gibbons, "TheExpertFlight Plan Critic," paper presented at 1 1th Conference on Interactive Videodisc in Education and Training, Arlington, VA, August 1989.

adapted for use there. Later, more elements, including training modules, maybe added to the system.[99]

A PSS (called "The Source") was developed for Prime Computer to put all the information needed by field personnel in one accessible place. The field personnel had entire bookcases full of data about the company's products, its customers and how they use the products (e.g., for computer-aided design), and its competitors' products. In addition, Prime had the usual training retention problems among their field personnel. Its PSS now provides most of this information on a portable computer that is networked to a mainframe for access to spreadsheets (allowing comparison of alternatives), the most recent cost data, and new product information. The PSS also includes job aids such as tables comparing Prime products with their competitors'.[100]

Ford Motor Co. is introducing a PSS called the Worldwide Engineering Release System. The mainframe CBT system, which cost $77 million to develop and implement and was translated into five languages, lists 400,000 automotive parts and more than 300 million pieces of data about them. It contains information useful to engineers about every part used in Ford products worldwide, including a part's engineering history, how long it has been used, its metallurgical makeup, and any current information about the part. For example, if a part isn't fitting into a bracket, the engineer can tap into the system to find out if any other plants have had similar problems and how they might have solved them. The system includes 25,000 training screens about parts, 1,600 simulations, and 1,500 assessment exercises. It also includes training on how to use the system.[101]

Another PSS was developed to assist insurance underwriters analyze risk. Risk analysis can take one of a number of approaches, and each underwriter is different. Thus, the sponsoring company felt that underwriters would resist an expert system that used one approach and made a decision. The company also felt that such a system would inhibit learning. Finally, a learner-controlled system was needed to address different experience levels and learning

99Ibid.

100Barry J. Raybould, "Building a Performance Support System: Comparing Alternate Development Platforms," paper presented at 8th conference on Interactive Instruction Delivery, Orlando, FL, February 1990.

101Geber, op. cit., footnote 3.

styles-to incorporate text, graphics, pictures, and sound. The relational database structure of a PSS filled these requirements.[102]

A final example is a PSS developed for Codex Corp. as a prerequisite for technical training. In essence, the PSS provides new hires with an introduction to their work environment by simulating a communications management job. It simulates the floor plan (complete with furniture and equipment) as well as the co-workers (animated computer graphics with audio). Databases provide information about the workplace (e.g., co-workers' backgrounds). Moving among rooms and selecting objects provide entry and exit points to the subject matter databases. Familiar office imagery (e.g., to-do lists, calendars, telephones) helps new hires get started. Opportunities to interact with colleagues and to get feedback from a mentor help trainees respond to increasingly complex challenges posed by the boss.[103]

Although technological developments made performance support systems feasible, technology alone will not promote their use, as it did with CBT. A PSS is difficult and costly to develop. Because the PSS is a new concept, decisions related to hardware and software are still experimental. An organization has to have a strong need to try something so different from normal training methods. One factor promoting PSS use (along with embedded training) is the frequent inability of conventional training to transfer to the job. In addition, a PSS can accommodate reams of information that can be updated easily and quickly. These systems also can adapt readily to different learning and working styles.

Digital Videodisc

Digital videodisc gets around the space limitations of analog systems. In general, the higher the quality of the audio or video reproduction, the more space it takes on a disc. A normal CD-ROM, for example, can store about 325,000 pages of text, or 72 minutes of CD-quality audio, or fewer than 500 high-resolution still images, or 30 seconds of full motion video.[104] Moreover, it would normally take over an hour for a PC to play back the 30 seconds of motion video from a CD-ROM. Compressing and digitizing the audio and video greatly expand CD-ROM storage and speed up the PC interaction. Digital encoding allows simpler delivery systems (with a single monitor handling digital text, graphics, images, video, and audio all played back from a single optical disk). Digital encoding also offers fine control of the contents and of each frame.[105]

Two forms of digital videodisc are being introduced-digital video interactive (DVI) and compact disc-interactive (CD-I). DVI uses an IBM PC/AT type platform with three custom boards and accompanying driver software, audio amplifier and speakers, and standard CD-ROM drive.[106] DVI eventually will compete directly with analog videodisc in training and education applications. IBM and Intel are collaborating to develop and market DVI for IBM's PS/2 line of PCs based on its micro-channel architecture. Both are sponsoring the development of several authoring systems. Moreover, they are establishing a joint technology center in Princeton, New Jersey to facilitate DVI acceptance, solicit customer requirements, disseminate technology information, and support application development.[107]

CD-I also will use CDs that store video images, audio, text, graphics, and data plus the software to support interactive use.[108] However, CD-I is being developed primarily for the consumer market. It is a packaged system, with its own unique hardware (player) that is hooked up to TV monitors and stereo systems, and has a UNIX-like operating system.

Digital videodisc provides all of the same potential advantages of analog in training applications, plus greater storage capacity. Because of its ability to integrate media, digital video has great potential in simulations. For example, split-screen capabili-

102Ann Farley, "The Individual Performance Accelerator: A Demonstration" paper presented at 8th conference on Interactive Instruction Delivery, Orlando, FL, February 1990.

103Madeleine Butler, "An Experiential Model for Learning Using Interactive Multimedia," paper presented at 11th Conference On Interactive Videodisc in Education and Training, Arlington, VA, August, 1989.

104G. David Ripley, "DVI—A Digital Multimedia Technology," *Communications of the ACM, vol. 32, No. 7,* July 1989, pp. 811-822.

105Edward A. Fox, "The Coming Revolution in Interactive Digital Video," *Communications of the ACM, vol. 32, No. 7,* July 1989, pp. 794-801.

106Development of DVI began in 1983 at RCA's David Sarnoff Research Center in Princeton, NJ. In 1988, Intel acquired the technology from General Electric, RCA's parent company.

107Karen A. Frenkel, "The Next Generation of Interactive Technologies," *Communications of the ACM, vol. 32, No. 7,* July 1989, pp. 872-881.

108CD-I was invented in the mid- to late-1980s through a collaboration among N.V. Philips (a Netherlands company), Sony Corp., and Microware Corp.

ties allow users to compare images selectively, either still or in motion. High-quality graphics can be combined with video for a trainee to display, for example, a cut-away schematic of a piece of machinery on one part of the screen, examine and manipulate a model of the machinery on another part, while hearing an explanation of the machinery's operation or repair. The trainee can also access other windows to get textual information on parts availability, different model numbers, and costs. High-speed animation can be used to simulate environments where it is impossible to film.[109]

Several of the test applications of DVI are in training. Applied Optical Media and duPont are developing a truck driver safety simulator. It is installed in a full-size truck cab (the whole unit can be moved with a forklift) in which all driver functions are simulated, with a DVI display providing views of 12 safety scenarios for the front windshield and both rear view mirrors. First a larger wide-angle view is decompressed, the portion of the view corresponding to the truck's current lane position is selected, and then the view is skewed to keep the distant horizon relatively fixed. This last step results in smooth, real-time lane changes, and is an example of the flexibility of digital video. Bethlehem Steel and Lehigh University are developing a casting simulator, Arthur Andersen is using DVI for manufacturing process analysis, and Carnegie Mellon has a workplace simulation for entry-level trainees.[110]

Because military training makes extensive use of simulation, digital videodisc may find a potentially large market there. One company is developing a DVI application for submarine maintenance training; another firm is developing an air defense program in which the operator identifies and tracks targets through actual terrain; a third is working on weapon maintenance training. (See report appendix for further discussion of simulation in the military..)[111]

However, digital videodisc still faces difficult technical problems. The cost of compression is high, special hardware and software are required, and efficient tools and environments for authoring and editing are still nascent.[112] Thus, digital videodisc probably will not supplant analog for at least 5 years and probably longer.[113]

Electronic Classrooms

While the availability of personal workstations and the extensive use of networks will make self-study and distance learning very common, a lot of training still will be classroom based for social interaction. Many future classrooms will have video projection capability, large monitors for PC projection, sound-activated cameras for remote interaction, and transponders to record learner responses. Instructors will show multimedia materials, access online databases, participate in teleconferences and videoconferences, and display real-time learning results.

Such electronic classrooms and meeting rooms already are being installed at some corporate learning centers and universities. IBM's Management Development Center at Armonk, New York, has 10 advanced technology classrooms in which the instructor uses a PC to control all audio and visual devices in the room including videotape, videodisc, slides, computer display, and lights. Each student has a keypad to respond to questions. The instructor and class can immediately see a display of the tabulated results of the class responses.[114] IBM found that students retain 83 percent of the information presented in the electronic classroom compared with 68 percent retention in traditional classroom training.[115]

In another concept, every learning station would have networked multimedia PCs, with the instructor controlling the displays. Introductory material could be presented to the entire class, and then students could proceed at their own pace. Feedback on student progress, aided by intelligent tutoring sys-

[109] Ripley, op. cit., footnote 104.

[110] Ibid; see also Sandra Morris, "Digital Video Interactive Technology Application Sample," paper presented at 11th Conference on Interactive Videodisc in Education and Training, Arlington, VA, August 1989.

[111] Ibid.

[112] Fox, op. cit., footnote 105.

[113] Frenkel, op. cit., footnote 107.

[114] Kearsley, op. cit, footnote 1.

[115] Geber, op. Cit., footnote 3.

terns, would enable the instructor to identify individual learning problems and display remedial materials.[116]

The more widespread use of PCs by instructors reinforces the trend toward electronic classrooms. If instructors become accustomed to preparing training materials on the PC (e.g., presentation slides, other graphics, multimedia programs), they will want to have a computer in the classroom to make use of the software. Similarly, computers in the classroom will promote their use in class preparation.[117]

Electronic classrooms are more expensive to build than conventional ones, however, and are beyond the reach of all but the largest corporate training budgets. Learning centers are one option for increasing access. Furthermore, because computer and media technology are evolving so quickly, the equipment installed in these classrooms becomes obsolete rapidly.[118]

Digital Networks

As noted in the discussion of teleconferencing, the U.S. Public Switched Telephone Network (PSTN) is moving toward a digital system with more capabilities. Eventually, the Integrated Services Digital Network (ISDN) will allow users to send audio, data, and video signals over the same line simultaneously, thus allowing transmission of electronic messages and other signals associated with CBT, teleconferences, and hypermedia. Although not all the relevant standards have been worked out, manufacturers are already making narrow band ISDN equipment (which does not allow full-motion video transmission), and there are more than 60 trials underway (none involving distance learning). Wideband applications of ISDN including video are not expected to appear until 1995 or be widely available until 2000. The services probably will include videoconferencing, high-speed data and fax, and HDTV.[119]

These networks will make the transmission of multimedia as inexpensive as voice. With technical and financial obstacles to tele- and videoconferencing reduced, network use should increase substantially. In conjunction with other developments in computer hardware and software, digital networks will greatly facilitate embedded training and distance learning. In many cases, training will become more informal and self-directed.

Glass Boxes

Smart job aids, such as computer help screens and automotive diagnostic tools, replace mechanical processes with information processing and radically change the way people use tools. Although they have reduced the need for retraining by transferring the burden of keeping pace with innovation from the worker to the systems designer, such aids also can stifle workers' use of intuitive skills. Good specialized auto mechanics, for example, are renowned for their intuitive grasp of how cars work and what to do when they stop. But opaque electronics have now replaced many of a car's mechanical systems-to the point that some modern cars are computationally more powerful than the average PC. Repair shops also have widely adopted electronic diagnostic systems that issue instructions without necessarily making either the diagnosis or the prognosis explicit. Both the car's electronics and the diagnostic system are ''black boxes' to mechanics, who must blindly follow instructions, and who are no longer able to monitor, reflect on, and correct their own working procedures. Nor do mechanics have much opportunity for useful conversation about their work—which traditionally has contributed to shared workplace knowledge. Mechanics are particularly helpless in the face of misdiagnosis or failure of the diagnostic system.[120]

A smart job aid that is under development to overcome these problems is a ''glass box' '—a transparent system that will help workers develop a deeper understanding of the process in which they are involved. Glass box tools are, like the journeyman or office expert, both a tutor and a fully operational component of the workplace. Glass boxes would break a task down into constituent parts that a trainee can understand and master separately.

116 'Classroom of the Future Addresses Student's Needs," *IST Review*, Summer 1989, pp. 2-3.

117 Kearsley, op. cit., footnote 1.

118 Ibid.

119 Office of Technology Assessment, *Linking for Learning*, OTA-SET-430, op. Cit., footnote 35.

120 Institute for Research on Learning, op. cit., footnote 50.

121 Ibid.

They also would provide a means for collaborative learning and for discussion of the task.[121]

In sophisticated machinery, however, the representation of working procedures is an extremely complex task requiring detailed research on the interaction between machines and workers. Much more work is needed in this area before good user interfaces can be designed that, with the help of multimedia devices, will provide workers with an adequate understanding of tasks while still allowing them to develop and use intuitive knowledge, thus fostering worker flexibility and innovation.[122]

Virtual Environments

Researchers also are working on systems that will allow people to interact with computers in profoundly new ways. In prototype systems, people wearing a special helmet and gloves feel immersed in three-dimensional computer-generated worlds and can control the computer by using their hands in a natural manner. Such advanced simulation systems are called artificial realities or virtual environments. The helmet contains two small television screens (one for each eye) that provide three-dimensional images and a sensor that keeps track of the position and orientation of the wearer's head. As the head turns, the computer-generated scene shifts accordingly. The glove has optical fiber sensors that detect how the hand is bending. A separate sensor determines the hand's position in space. A computer-drawn image of the hand appears in the display, allowing the user to guide the hand to objects in the simulation.[123]

Virtual environments are still in the basic research stage (a complete system may cost $100,000 to $200,000 and an enormous amount of computer capacity is needed to generate the images), but commercial and military interest is beginning to develop. Virtual environments could substantially reduce the size requirements for flight simulators, for example (see appendix). They also would be useful for manipulating remote objects (e.g., robot arms) and for work in space. The glove alone already is being used in computer-aided design in lieu of a keyboard or mouse (and in advanced video games). Companies also are researching full body suits that would allow types of body movement to control a simulation, and allow incorporation of two or more people in a virtual environment (e.g., a pilot and copilot, a virtual meeting). The participants would not need to be in the same location, but could be linked on digital networks.[124]

121 Ibid.

122 Ibid.

123 Andrew Pollack, "What Is Artificial Reality? Wear A Computer and See," *The New York Times,* Apr. 10, 1989, p. A-1.

124 Ibid.