Processes of Work-Based Learning 3

OTA has identified several processes by which knowledge, skills, attitudes, and habits develop during work-based learning. These processes are experiential learning, work-group learning, mentoring, workplace instruction, and technology-assisted learning. The first can occur solely at the learner's initiative, but all the rest involve intentional efforts by others to contribute to the young person's development.

Work-based learning generally differs from school-based learning in a number of ways. In school, students are involved primarily in individual activities, whereas in a work setting the students often undertake activities with other members of the work group. In school, students are engaged primarily in mental activities, whereas in a work setting the students combine those abstract activities with concrete ones. In school, students are directed toward developing competencies that are believed to be generalizable, whereas in a work setting most learning focuses on specific tasks, equipment, and procedures. Finally, in school, students generally use few tools, whereas in the workplace the use of tools is pervasive (53). Several examples of work-based learning activities are described in box 3-1.

Good work-based learning has an authenticity that probably cannot be replicated in school-based learning. The students are expected to assume adult responsibilities, working in adult peer groups united by a common enterprise of producing goods and services. To succeed, the students depend on their co-workers, and the co-workers, in turn, depend partly on the students. The students must learn to use unfamiliar equipment, follow specific work procedures, and adapt to the norms of the workplace. They must coordinate both abstract thinking and hands-on activity. They must also learn to deal with the emotional pressures that

BOX 3–1: Examples of Work–Based Learning Activities

- Help an experienced employee: The student helps an experienced employee with various tasks. The student usually begins doing the simplest and least critical parts of the job, and gradually moves up to the more skilled activities. The experienced employee explains, demonstrates, and guides the student in practicing.
- Work under close supervision. The student assumes work responsibilities under close supervision. The supervisor may provide orientation to the responsibilities, directions, feedback on performance, warning of impending problems, correction of mistakes, encouragement, and advice on handling unexpected contingencies.
- Work with minimum supervision: The student works with minimum supervision, usually after proving himself or herself when working under close supervision.
- Participate in a "community of practice": The student participates in informal exchanges of reformation and assistance among employees with similar responsibilities. At first, the student is generally the beneficiary of such exchanges, but with growing experience the student becomes increasingly a contributor.
- Participate in "occupational communities": The student participates in professional organizations, industry associations, or unions that span more than one organization. The student may read the communities' publications, attend their meetings, and socialize with their members.
- Explore and innovate: The student seeks to develop superior work procedures, and then tests, refines, and incorporates them into his or her work. The procedures may also be adopted by other workers or throughout the organization.
- Orient, tram, and supervise: The experienced student orients, trains, and supervises entering students and perhaps other entering employees.

SOURCE Off Ice of Technology Assessment, 1995.

result from high production goals, rush orders, equipment breakdowns, nasty supervisors, feuding colleagues, irate customers, business slowdowns, and the possibility of layoffs.

"If you've accomplished this program, you could do anything. ANYTHING. Try and stress me out—you couldn't do it. "-Student (28).

Work-based learning yields knowledge, skills, attitudes, and habits that arise from interaction with the organizational structure, equipment, materials, work procedures, and personalities of a given workplace. An OTA contractor has identified seven types of knowledge and skill that are necessary for most work (5):

1. **Sensory interpretation** involves making inferences based on colors, shapes, patterns, sounds, smells, tastes, and tactile clues—perceived directly or with the aid of instruments. For example, machinists who use the latest numerically controlled machine tool still listen for minute changes in pitch and tone that indicate problems in how the cutting surfaces are contacting the raw materials. X-ray technicians make three-dimensional inferences from two-dimensional film images.
2. **Sensorimotor dexterity** is the "feel" for the instruments, materials, and techniques used in a given occupation—not just familiarity but, rather, tactile sensitivity. For instance, laboratory technicians learn that when pipetting a cell culture, just the right touch is required to avoid destroying the sample.
3. **Tricks of the trade are** plans of action that have been developed by practitioners from a combination of experience, tacit understanding, and formal scientific knowledge. For instance, sonographers, when scanning for the presence of a suspected gallstone, know that they can most easily identify the problem by rolling the patient on his or her side and looking for the stone to "drop" on the screen.

4. **The local history of problems** is the accumulated knowledge of the causes, timing, and fixes of problems that have recurred over a period of time. For example, workers may have learned that a particular piece of equipment will tend to malfunction in unusually hot temperatures.
5. **Work style** is the set of work roles, social skills, norms, and customs that guide how work is conducted. For instance, emergency medical technicians generally adopt a decisive, improvisational, and coolly detached work style to cope with the life-threatening and chaotic circumstances under which they work. Work styles vary considerably among occupations and organizations. Even for a given occupation, there will be modest differences across organizations and sometimes across work groups within a single facility.
6. **Coordinating activities** organize and focus the general knowledge, technical expertise, and organizational status of different persons involved in a work task. For instance, emergency medical technicians often must work closely with fire fighters and police officers at emergency scenes, sometimes directing the coordination and sometimes responding to the directions of others.
7. **Linguistic skills** involve the use of occupational jargon and its translation for nonspecialists. Automotive technicians use terms such as "dogging," "traming," "zerk," and "chuggle," when talking among themselves, but must translate those terms into common English terms when talking with customers.

Although school-based occupational education can contribute to the development of each of these types of knowledge and skills, it is rarely able to fully prepare students for the workplace. Schools cannot afford to have all the equipment and tools that young workers must learn to use. Students often underestimate the importance of knowledge and skills until they experience their use in a real workplace. The requisite knowledge and skills will vary from one workplace to another, and even among different work groups within a given facility. And the latter four types of knowledge and skills just described require complex interactions with other employees.

In addition to having several advantages, work-based learning has some potential disadvantages. Workplaces are organized for efficient production, distribution, and customer service, not for efficient learning. American businesses historically have provided relatively little training for their nonmanagerial employees and have encountered difficulties in preparing incumbent employees for new technology (61,66). The supervisors and mentors may be preoccupied with other responsibilities and unable to give the students the necessary encouragement, guidance, and feedback. The easiest thing to do with low-skilled young people is to give them the menial work that nobody else wants to do. Although important lessons can be learned from such work, most students will master the lessons in a matter of weeks and learn little thereafter. Even when a conscientious effort is made to provide the young people with a variety of learning opportunities, several of the types of knowledge and skills cited above are likely to be partly idiosyncratic to a given workplace, and thus mastery of these in one worksite is not likely to yield adequate preparation for other worksites.

One researcher noted, "Students do not seem to be held to authentic workplace standards across the board, although that seems to be the goal of each employer" (28).

STWOA anticipated most of these problems, but that does not assure they will be effectively countered. STWOA calls for work-based learning to include "a planned program of job training and work experiences (including training related to pre-employment and employment skills to be mastered at progressively higher levels)" (Public Law 103-239, Title I, Sec. 103[a][2]). It calls for the provision of technical assistance and services to employers to help them design the work-based learning and to train workplace mentors (Title I, Sec. 104[3]). The work-based learning is to include a "broad introduction, to the extent practicable, in all aspects of the industry" (Title I, Sec. 103[5]). And the work-based learning and school-based learning together are to prepare the youth to earn "a portable, industry-recognized credential" of skill (Title I, Sec. 103[a][2[and Sec. 4[22]).

Five work-based learning processes (experiential learning, work-group learning, mentoring, workplace instruction, and technology-assisted learning) are discussed here. OTA found no reliable evidence on the extent to which each of the processes is used in work-based learning or on their relative effectiveness. Because each appears to have both advantages and disadvantages, the richest learning experiences probably will involve combinations of several. Although STWOA broadly stipulates the objectives and content of the work-based learning, it leaves the actual processes to the discretion of the state and local systems, with the exception of mentoring, which is required. In addition, the various models of work-based learning that are discussed in chapter 5 are not differentiated by the processes of work-based learning that they use. Each model can use any of the processes.

EXPERIENTIAL LEARNING

In the broadest sense of the term, experiential learning occurs when students learn from activities that are unintentionally instructive. When students observe how things are done in the workplace, reflect on the reasons for those practices, assume new roles and note their consequences, encounter a problem in their work and manage to solve it, or experiment with improving some work procedure, they are engaged in experiential learning.

Whereas the benefits of experiential learning are widely recognized in the adage "Experience is the best teacher," the shortcomings are also recognized in the quip "The school of hard knocks is a good teacher, but the tuition can be steep." Experiential learning is limited by the range of firsthand experiences available to the student, it is often slow, it can easily lead to false inferences, and it can result in harm to the learner or hazards to others (58). Hardly anyone becomes proficient in the use of word processors without some instruction or reference to a manual. And few people would volunteer as subjects for nurses who are experientially learning to draw blood.

Work-based learning programs often try to guide experiential learning in ways that harness the benefits and minimize the limitations. One way of doing this is to encourage experiential learning only after conveying the fundamentals and alerting students to common hazards by other means of learning. A second way is to provide structure to the experiential learning that will focus and accelerate it, for example, the use of learning plans that specify the objectives and sequence of the workplace activities. A third way of optimizing experiential learning is to supplement it with exercises that help students reflect on their experience. In some programs the students are asked to keep a journal of their work experience; in other programs the students attend a seminar that helps prepare them for their work-based learning experiences, deal with problems that may arise, reflect on what they have learned, and consider the social, economic, and ethical contexts of work.

Todd

Todd had been doing well in the worksite, and had earned the affection of his supervisor and co-workers. But he repeatedly failed to complete the assignments for the school seminar that accompanied the work experience, and school officials eventually removed him from the program. The supervisor was dismayed, and responded by hiring him back as a regular part-time employee (67).

The Cambridge Rindge and Latin School requires enrollment in such a seminar for all juniors and seniors participating in internships. The students study the historical and social aspects of work, reflect on their work experience in writing, and plan their end-of year projects (67).

LaGuardia Community College in New York City has developed an elaborate series of seminars to accompany its cooperative education work assignments. The seminars foster exploration of careers, development of intellectual and occupational skills, and reflection on the social and ethical aspects of work. When students are nearing eligibility for work-based learning, they attend a 12-hour preparation course that introduces them to the co-op program, helps them assess their interests and skills, requires them to establish objectives for their career and work assignments, and prepares them for the job search process (23). During the first semester of work-based learning, the students attend an evening or weekend seminar to plan activities in the workplace that will deepen their understanding of how the organization is structured and operated. These activities might include preparing organization charts, identifying leadership styles, describing the document flow, and analyzing ethical dilemmas. During the second semester of work, the students engage in several career exploration exercises and develop strategies for deriving maximum learning from their work experience. These strategies include seeking challenging assignments, coping with hardship, and requesting feedback on one's strengths and weaknesses. During the third semester of work, the seminar helps the students prepare a research paper that draws on the theory they have studied and the work experience (23).

WORK-GROUP LEARNING

Work-group learning is an immersion approach to work-based learning. The learning comes from sharing the activity and the distributed knowledge of the group. Members of the group model the work procedures and exert pressure on each other to enforce the established norms. They attend to important cues from their colleagues and supervisors and ignore the unimportant ones. They converse—asking questions, responding, and offering unsolicited information necessary for the group's work. They tell "war stories" about work crises, their responses, and the outcomes. They help each other. They call on outside resources when appropriate, and they coordinate with the other work groups (47).

Newcomers to a work group usually begin on the periphery, where the tasks are short and easy, the costs of errors are small, and their responsibility for the activity as a whole is small. As the newcomers master the simpler tasks, they are given more complex ones, thus moving from the periphery to the center of activity (39). Full participation in a work group is characterized by having the ability to access and contribute to the group's collective memory, knowing when to disregard the rules, being recognized as an "old hand," and having power to affect the life of the group in important ways. Learning enables new people to enter work groups and to move toward full participation.

Several types of work groups can be important to work-based learning opportunities. The first is an occupationally heterogeneous face-to-face work group, for example, a physician's office that has a receptionist, a part-time bookkeeper, two nurses, and a physician. The members of the group have complementary skills and responsibilities. A second type of work group is an occupationally homogeneous face-to-face group, for example, the equipment repair department of a large hospital, which would be staffed with several electronic technicians who share responsibilities, though there may be some specialization according to individual skills and preferences. A third type of work group is an occupationally homogeneous group composed of people within a given organization who seldom work face to face, but communicate and associate informally to share expertise and to experience camaraderie. The second and third types of work group are increasingly referred to as "communities of practice."

Another type of work group includes professional and trade organizations, the chambers of commerce, unions, computer-user groups, and informal groups of people engaged in similar occupations. The members of these groups generally do not work together, but they engage in similar work, have common values and perspectives toward their work, and engage in social relationships that meld leisure activities and the expansion of work knowledge and skill. These are sometimes referred to as "occupational communities."

Work groups offer many opportunities for learning the types of work knowledge and skills discussed earlier. New members can observe experienced members using their tricks of the trade. The means of accessing the local history of problems can be overheard in conversations, observed, or explained at the newcomer's request. In one airline operations room it was observed that the staff addressed their questions aloud to the whole room, and anyone who knew the answer responded (32). The jargon of a work group and skill in translating it for nonspecialists can be gleaned by overhearing conversations and by listening to pointers from the experienced members. The coordination of work tasks can be learned by observation and by trial and error.

Adoption of the prevailing work style is crucial to avoiding trouble and to becoming a full member of a work group. For example, a routine-obsessed and fastidiously clean work style is necessary for medical technicians who deal with cell cultures that can easily be contaminated (4). New employees may receive formal orientation to the key elements of the work style, but subtleties are learned by observing the experienced workers, interacting with them, asking questions, feeling peer pressure, and sometimes suffering sanctions.

Two scholars have observed, "Work would be practically impossible and unbearably stressful if practitioners could not rely on one another to supply needed information" (5). That reliance provides reciprocal incentives for learning and for facilitating learning. Newcomers depend on the older members, but the older members will eventually have to rely on the newcomers.

Sometimes the messages that work groups convey to new members are too subtle to be detected; at other times the demands of the group can overwhelm the novice. In addition, the lessons learned from work groups are not always positive. The productivity and efficiency of work groups can range from low to high. Some groups resist all change, and others perpetuate racial and gender discrimination. Participation in a good work group can be a great learning experience; participation in a bad work group may teach dysfunctional lessons.

MENTORING

Mentoring is a relationship in which a more experienced person facilitates the broad development of a less experienced person on a regular basis and over an extended period of time. Mentoring in work-based learning can be directed primarily toward occupational development, but usually it is equally directed toward intellectual, personal, and social maturation. The mentors in work-based learning may be responsible for:

- acquainting the students with the formal rules and informal norms of the workplace;
- introducing the students to the people and resources outside the immediate work area;
- inculcating positive attitudes and work habits;
- guiding the students in development of work knowledge and skills;
- encouraging and helping the students to undertake challenges;
- encouraging the students to reflect on their experiences;
- serving as a confidant in times of stress;
- providing empathy, support, and encouragement when the students encounter difficulties;
- providing sympathetic but realistic feedback;
- helping the students to view things from other people's perspectives;
- serving as a protector, facilitator, and advocate;
- introducing the students to occupational and industry associations;
- helping the students plan for subsequent education and training; and
- serving as a personal and professional role model.

One example of mentoring that is aimed at intellectual and occupational development is provided in the following account:

> He [Peter, the mentor] lets him [Richard, the student,] first grapple with a problem and stretch his resources, but intervenes before Richard gets frustrated. When Richard does come for help, he is not automatically given the

> solutions, because Peter sees that as counterproductive in two ways. First, problems have several solutions. And second, solving the problem is not the primary purpose of the dialogue for Peter; it is also to give Richard new ways to approach the problem so that in the future he might become yet more resourceful because of a bigger knowledge base and understanding of the variables in the problem (27).

STWOA specifies that the work-based learning "shall include . . . workplace mentoring" (Title I, Sec. 103[a][3]). In addition, each student is to be provided with "a school site mentor to act as a liaison among the student and the employer, school, teacher, school administrator, and parent of the student, and if appropriate, other community partners" (Title I, Sec. 104[2]).

Indirect support for the benefits of mentoring comes from at least four lines of research. Several studies of unusually effective adults have found that they more often report having had a mentor than do less successful adults (33,43,54). Considerable evidence indicates that children who do well despite a deprived childhood have had the benefit of at least one caring and attentive adult (21,56,68). Research indicates that the extent of student contact with college faculty is associated with college success (2,13,50,62,69). And a review of more than 100 reportedly successful programs for at-risk youth concluded that their distinguishing features were intensive individualized attention by one or more adults and communitywide prevention and support services (17). These studies, however, generally have not controlled for the possibility that young people who establish strong relationships with adults may have been psychologically and socially stronger than others before establishing those relationships.

There is only scant mention in the literature about negative effects of mentoring. One of the few substantive discussions of possible adverse effects is from the literature discussing the mentoring of adults. It suggests that although mentoring relationships can be quite positive experiences, they can sometimes be ambiguous, conflictual, and disappointing; they can minimize the protégé's contacts with others; they can create an illusion of great caring that subsequently is shattered; and they can lead to sexual exploitation (5). The frequency of these problems is not reported.

Over the past decade many programs have used volunteer mentors as buddies, confidants, and role models for disadvantaged youth. There are credible accounts of how these mentoring relationships transformed the lives of some floundering youth, but the overall picture has not been encouraging. The programs have frequently had difficulty recruiting and retaining adequate numbers of mentors (20,27,44;45). Only about one-third to two-thirds of the matches become significant relationships (20). For those few programs that have been rigorously evaluated, the programs have shown little or no effect on the students' school attendance, academic achievement, graduation rates, or enrollment in postsecondary education (29). When the volunteer mentoring has been combined with tutoring or college orientation, the results have been only modestly better (9,44,51,). None of these evaluations report the potential problems mentioned earlier. Rather, the disappointing results appear to have been due to difficulty in establishing and maintaining good mentoring relationships, and to limited effects even when good relationships are established.

In contrast, the four-year-long Quantum Opportunities Program (QOP)—with mentoring done by full-time paid staff, in combination with supplementary academic assistance, developmental activities, community service options, and financial incentives—had very strong effects in four out of the five sites that succeeded in implementing the program. The program resulted in a 50 percent increase in high school graduation rates, almost a threefold increase in postsecondary enrollments, a 37 percent drop in childbearing, and a 50 percent drop in arrests (24,25). These improvements are among the largest ever found for a youth development program. Given the array of services, it is impossible to know the extent to which mentoring contributed to the outcomes, but several observers agree that the personal ties with the supportive adults were an important element.

There are reasons to think that the workplace mentoring anticipated in STWOA will have advantages over the community-based mentoring programs just described. Workplace mentoring will be more convenient because the mentors will be the students' supervisors or other experienced employees, and will not have to travel to and from the protégés' homes or deal with the frustration of unanswered phone messages (a common problem in community-based mentoring programs). There will be a core of common interest as the young person tries to adapt to a work environment in which the mentor is well established. The mentoring can be provided as needed, rather than on a prearranged schedule. In addition, the mentoring is to serve a broad cross section of youth, not just disadvantaged youth, who generally have the greatest needs and often are the most difficult to assist (20).

Although the highly successful QOP had a very limited work-based learning component, it is similar in several respects to the mentoring that is to be provided under STWOA. QOP used mentoring in the context of other educational and developmental activities. It used mentoring to address the current needs of the youths and to raise their horizons. And it provided mentoring and other services on a sustained basis for several years.

A review of several ethnographic and case studies of school-to-work transition programs has identified mentoring as commonly associated with student development. The authors conclude:

> Of unquestionable importance is the "vet," "master teacher," or skilled mentor who situates learning in authentic practice; has adequate resources; establishes a culture of achievement; and understands how roles/relationships in the workplace progress over time to enhance the growth and development of the novice (7).

OTA staff found only one formal evaluation of mentoring in work-based learning. Although it is based solely on the perceptions of the young people's development, measured by students' and mentors' responses on a rating form, both groups agreed that mentoring contributed to the youths' knowledge about workplace rules and behavior, to their ability to follow directions and take initiative, and to improvements in their communication skills (18).

Several tentative lessons for implementing worksite youth mentoring can be drawn from the general literature on mentoring and from the demonstrations cited earlier:

- Mentoring appears to work best when professional staff help prepare the mentors and protégés for mentoring and give them continued support after the match-up (10,46,51).
- Matching of mentors with young people on the basis of race/ethnicity and gender does not appear as important as popular opinion has suggested, but there should be an effort to assure personal compatibility and correspondence in interests (30,46,51).
- Mentors should be prepared to listen and provide emotional support to the protégés (20).
- Limited evidence suggests that relatively immature youth need a great deal of encouragement and guidance to develop and maintain responsible behavior, whereas more mature youth will benefit from a focus on career and occupational issues (18).
- The mentoring should also help the youth explore new experiences, make contacts, assume responsibility, gain self-discipline, learn job-seeking skills, and solve personal problems (10,18,46).

WORKPLACE INSTRUCTION

Workplace instruction includes formal lectures and presentations to large groups, informal talks and demonstrations to small groups, and the coaching of individuals. The training may be provided by management, supervisors, expert employees, or outside consultants.

One of the challenges facing American businesses is to prepare new and incumbent employees to deal with rapid change and complex technology. Skills in innovating, organizing, troubleshooting, problem solving, and continuous learning are needed to face these challenges. The rest of this section discusses a new approach for developing complex cognitive skills such as these. This approach has come to be called "cognitive apprenticeship" (12).

The cognitive apprenticeship approach was first used in school settings to teach advanced skills in subjects such as reading, writing, and mathematics. The approach has not yet been used extensively in work-based learning, but it appears to have potential for improving the teaching of intellectually demanding workplace skills.

Cognitive apprenticeship involves three phases: modeling, coaching, and exploration. Although these phases may be introduced in that order, the mastery of complex skills often involves moving back and forth among the three phases.

The expert usually begins by modeling the entire complex skill in the context that it would be used, and then may repeat several components of it. Because cognitive functions cannot be directly observed and often cannot be correctly inferred by observing a person's behavior, the expert usually gives a running commentary while modeling the skill. Producing such commentary often takes some practice, because experts rely heavily on "tacit knowledge and processes" of which they are not fully conscious.

In the coaching phase, the expert guides the student through the practice of the skill. The guidance can be in the form of verbalizations, physical assistance, and emotional encouragement. Through repeated trials and successive approximation, the student gradually reaches mastery and automaticity. The initial guidance may be substantial, but once the student begins to grasp the skill, the guidance is reduced to the minimum necessary for the student to succeed with effort. Directions are replaced with hints and questions; continuous feedback and detailed debriefings are replaced with occasional comments; and effusive encouragement may be replaced with a more reserved respect.

The extent of guidance is deliberately reduced so as to require the student to develop and rely on his or her own resources. These resources include monitoring one's own performance and correcting shortcomings in performance. These capabilities are so critical to mastery and maintenance of complex skills that the expert will deliberately guide their development during the coaching phase.

To help monitor the student's progress, the expert may ask the student to think out loud when practicing. The expert's own running commentary during the modeling phase serves as an example of how to do this.

The student is prepared for the exploration phase by being given increasingly complex tasks and more broadly defined assignments. In the exploration phase itself, the expert encourages the student to choose problems he or she can tackle with the knowledge and skills already acquired. The student is asked to set the objectives, frame the questions, and define the problems. At first, exploration usually results in the student's "reinventing the wheel," but as he or she becomes more knowledgeable and proficient, exploration sometimes results in innovative products, services, or work processes.

The cognitive apprenticeship approach has not yet been used enough in workplace instruction for its effectiveness to be determined. Its obvious strength is the emphasis on developing the complex cognitive skills that are thought to be increasingly needed in the workplace—an emphasis that is missing from some other forms of training. A potential limitation is that this emphasis on development of complex skills is at the expense of the acquisition of extensive knowledge, which has been found to be important for expert performance in varied situations (22,60). As a result, the approach probably should be supplemented by other instruction, except when the students are already quite knowledgeable.

When cognitive apprenticeship strategies have been used in developing advanced reading, writing, and mathematics skills in schools, they have been moderately more effective than traditional approaches (12,34,55). One of the reviews, however, found that the effects were greater when the approach was combined with didactic teaching (55).

TECHNOLOGY-ASSISTED LEARNING

Technology-assisted learning is based on a wide range of equipment ranging from VCRs to computers. This section focuses exclusively on computer-based technologies because they have undergone the most profound changes over the past decade and appear to hold considerable promise for work-based learning and school-to-work transitions. Computer-assisted learning can help prepare students for work-based learning, assist them during work experiences, and supplement those experiences.

Computers, the software they use, and their peripheral displays permit many forms of computer-assisted learning. Although the functioning varies considerably, computer-assisted learning generally offers several advantages: Substantial expertise can be enlisted in the planning and preparation of instruction, and then delivered each time the instruction is reused. The assistance can be used as needed and when most convenient. There can be considerable interaction, allowing the students to actively apply what they have learned. Students can proceed at their own pace, follow paths of their own choosing, stop or backtrack when necessary, and review their past performance. The students' understanding can be tested frequently and corrective feedback can be provided immediately. Increasingly, the technology can identify error patterns and tailor instruction to the students' knowledge, skills, and preferred learning proclivities.

Technology-assisted learning also has several drawbacks: Most forms have high initial costs for preparation of the software; one recent study found that an average of 228 person-hours were required to create one hour of computer-based training (52). Widely commercialized software can cost as little as $50, but custom software sometimes costs several hundred thousand dollars. Some of the software cannot be modified by teachers or supervisors to accommodate local information or an individual organization's practices. Technology-assisted learning lacks the human touch that encourages students and sometimes inspires them. And the technology is changing so rapidly that obsolescence is assured every few years, although older equipment and software can be used in a diminished capacity for many years after it has become dated.

In addition, many schools and small workplaces are ill-prepared to make widespread use of technology-assisted learning. They lack the necessary electrical service, telephone lines, and network wiring. They also frequently do not invest in the staff training and support needed to make good use of the technology (64,66).

The reviews of research on various computer-assisted learning technologies have repeatedly found that students generally learn more in less time than is the case with traditional teaching (3,19,37). The evidence on cost-effectiveness also is generally favorable (19,41). It should be noted that most of these reviews are of technologies used five to 15 years ago, which are most comparable to the career information delivery systems and computer-based training that are described in the next section. Less is known about the effectiveness of the other technologies discussed there. Yet, over the past decade the cost of computer equipment has dropped dramatically; as a result, the cost-effectiveness of all forms of computer-assisted learning has improved rapidly.

Technology-assisted learning for work-based learning relies on products targeted at one of four markets: high school and college students who are engaged in career orientation and occupational preparation, incumbent workers who need to upgrade their skills, experienced workers who use computers as tools in their work, and the entire computer-using population. School-to-work transition systems and work-based learning do not yet amount to a distinct market. That situation might change in the future, but even if it does not, the other four expanding markets will drive further developments and refinements that will be of use for work-based learning.

OTA, with the assistance of contractors, has identified the following computer-based technologies that appear to have good potential for use in work-based learning: career information delivery systems, computer-based training, intelligent tutoring systems, hypermedia, computer-supported collaborative learning, computerized simulations, and business applications software (15). Although each is discussed separately here, two or more of the technologies are sometimes combined.

Career Information Delivery Systems

A recent survey identified 25 computer-based career information delivery systems (48). Most of them help students assess their interests, aptitudes, and generic work-related skills. Some use the results of those assessments to suggest occupations that might be good choices for the students. Most provide a wealth of information on hundreds of occupations. The information usually covers the nature of the work, working conditions, range of earnings, training requirements for entry and advancement, and job prospects. Some provide information on local job prospects and local training providers. Some also give guidance and training in searching for jobs (15).

Career information systems have evolved considerably over the past two decades and are likely to continue progressing, but several limitations currently prevent widespread use. The limitations include expensive software that generally is available only at some schools and training organizations, systems that are not particularly attention-grabbing and thus require self-motivated students, the need for modest computer fluency to operate the systems, a lack of connection to state and national job listings, and little assistance directed at helping students weigh the advantages and disadvantages of alternative occupations that they have selected as good prospects. Because of these limitations, it is often suggested that students should use the systems with the assistance of a well-trained guidance counselor. There also has been little rigorous evaluation of the effectiveness of these systems (15).

Computer-Based Training

Although this term is sometimes used broadly to refer to all forms of computer-assisted learning used for occupational development, it is also used more narrowly to mean instruction that takes the student through a didactic presentation of concepts, facts, and skills, interspersed with tests and immediate feedback. Simple computer-based training was first developed in the 1960s. It is like a textbook with frequent quizzes that are automatically scored. A student who does poorly on a quiz is told to go back and repeat the module. More sophisticated computer-based training offers students some opportunities to choose among alternative approaches to instruction, such as a careful explanation or a quick review.

Computer-based training is well suited to transferring knowledge of facts and specific procedures, and both are widely needed in the workplace. Reviews of the extensive research on the use of computer-assisted learning that is similar to computer-based training suggest that it has reduced learning time by some 24 to 34 percent (37).

Computer-based training generally cannot judge constructed responses such as a sales speech or a creative solution to a problem, and it has very limited potential for developing teamwork skills. In addition, local teachers and workplace mentors generally cannot modify the presentations or add new modules.

The development of simple computer-based training can require as little as 10 hours of preparation per hour of instruction, but sophisticated training can require 100 to 228 hours for an hour of instruction (14,52). The high costs can be justified when traditional training is very expensive or dangerous, or when the computer-based training can be used by large numbers of students with little assistance from teachers.

Computer-based training is already well commercialized, but development costs and the inability to modify the instruction locally are major barriers to wider use. Several vendors have developed "authoring" tools that partially automate the development of the software and make it modifiable by teachers, but these tools allow only a very limited set of instructional strategies.

Intelligent Tutoring Systems

Intelligent tutoring systems apply "artificial intelligence" for the purpose of effectively guiding human learning. The tutors are designed to detect what the learner knows, compare that knowledge with what is to be taught, create an optimal learning path, recognize patterns in the learner's errors, and provide error-specific feedback. For instance, if a learner is having difficulty, the tutor might try another approach that appears to be more appropriate, provide explanations of why certain answers are wrong, and give the learner more encouragement.

A prominent example of intelligent tutors is provided by SHERLOCK. This system trains Air Force electronic technicians to diagnose problems in a complex device used to service the avionics of F-15 jets. SHERLOCK displays on the computer screen depiction's of the device, schematic diagrams of the electrical circuits, and system documentation. The tutor "creates" a fault in one or more of the circuits of the device and asks the trainee to locate the problem. The trainee selects the circuit diagram he or she thinks should be tested, marks where the probes of the diagnostic equipment are to be placed, "activates" the equipment, and receives simulated readouts. After considering the readouts, the trainee decides whether there is a fault in that tested part of the circuit. The process is usually repeated many times, attaching the probes to various circuits, until the trainee determines the location of the fault. If the trainee is clearly misdirected or proceeding inefficiently, the computer provides feedback and guidance based on constant monitoring of the progress. In addition, whenever the trainee wants help, the computer will provide it (38).

Intelligent tutors are well suited to developing complex skills. When connected to mechanical devices manipulated by the learner, such as control panels and steering wheels, intelligent tutors can help students develop psychomotor skills. They can also be used to teach social interaction skills, such as customer service strategies, using video clips to model customers and expert customer service agents. Intelligent tutors generally cannot, however, judge the adequacy of a complex response such as a memo or graphic design, although some progress is being made along these lines.

Intelligent tutors are relatively new, and few have been well evaluated. Of those few, some have demonstrated dramatic results. A system for teaching college students a computer programming language was found to be 30 to 40 percent more effective in 30 to 60 percent less time (1). With just 20 to 25 hours of use, SHERLOCK allowed the average novice technician to achieve troubleshooting proficiencies exceeding the average for senior technicians with years of experience (40). The effectiveness of SHERLOCK is due partly to the speed with which the simulations can be "worked" by the novice technicians, partly to the "intelligence" of its tutor, and partly to the fact that the system deals with complicated problems that occur so infrequently that some senior technicians have never encountered them.

The cost of developing intelligent tutors is very high because of the diagnostic, modeling, and tailored-response capabilities of the systems. Several efforts are under way to reduce the cost by developing "common architecture's," reusable software codes, or "authoring" tools, but none has yet proved to be of general use. Another barrier to widespread use is the fact that the systems usually cannot be modified by the teachers or worksite personnel. Though some stunning examples of intelligent tutors have been developed, considerable advances will be needed if intelligent tutors are to be widely commercialized (15).

Hypermedia

Hypermedia comprises a vast collection of text, still images, animation, video, voices, sounds, and music, with linkages among all related items. Rather than providing a learning path, it presents the student with a "knowledge web" to navigate. Hypermedia relies largely on experiential learning, with some applications providing moderate guidance to the students..

Apple Computer has developed its ARPLE database to familiarize new and experienced sales-people with the vast and ever-changing catalogue of its own products and third-party software for Apple machines. Multilevel menus access background information, instructions, competitive analyses, "slide show" presentations, and demonstrations of various software. The CD-ROM version is distributed to approximately 5,000 Apple employees and 25,000 retailers. A survey of field employees judged ARPLE to be the best means they have for keeping informed about new products (36).

The Institute for Learning Sciences at Northwestern University is combining hypermedia with an intelligent tutoring system to teach social studies and journalism skills to high school students.. The "Broadcast News" program gives students a rough draft of a television news story and access to a hypermedia database that includes video clips and reference works. Students are asked to edit the video and voiceover to eliminate bias, correct factual errors, and fill in missing details. The students mark the parts of the text that they wish to change and then select among many offered options. At any time the students can query the hypermedia database, selecting questions they want answered by experts, browsing among reference works, and examining a collection of video clips. An "artificially intelligent supervisor" evaluates the students' edited versions of the story, provides detailed feedback, and determines whether the stories are ready for prime time. If so, the system allows the student to act as anchor of the news broadcast. The system also creates a video of each student's broadcast, which then can be compared with videos by other students and with professional news presentations of the same event (35).

Hypermedia can provide huge amounts of easily accessible information and can accommodate students' varying preferences for text, audio, and graphic presentation of information. It allows all the students to seek answers they need while bypassing other information. It is also relatively inexpensive to prepare, and often can be modified by local teachers and supervisors. Until recently, hypermedia databases have been stored on the hard disks of computers or on CD-ROMs and videodisks. The Internet and the forthcoming National Information Infrastructure will allow anyone with a properly equipped $1,500 microcomputer and a telephone line to access huge collections of data, text, and graphics in the world's libraries.

Hypermedia has several shortcomings. The systems are essentially passive, and to make good use of them, students must be goal oriented and able to work in an unstructured environment. Even then, failure to select effective search strategies can leave the student browsing through large quantities of low-priority information. "Webcrawler" and "knowbot" software is currently being developed to assist in the searches, but good knowledge of both the subject matter and the indexing system will probably remain important to conducting well-targeted and thorough searches. In addition, some developers have focused more on the pizzazz of impressive graphics than on the substance of the database.

The research on hypermedia suggests that navigating these systems builds the valuable information-finding and information-filtering skills that are increasingly necessary for effective functioning in high-tech workplaces. Independent learners do well with hypermedia, but those who need structure and guidance may flounder (15).

Hypermedia, as a reference mechanism, is already commercialized. As a tool for learning complex concepts and skills, it will need to be linked to other technologies, such as intelligent tutoring systems, and efforts to do that are still in the developmental phases (15).

Computer-Supported Collaborative Learning

Computer-supported collaborative learning is accomplished by an array of technologies, most prominently, "groupware" decision support systems, collaborative design tools, and telecommunications. These technologies allow a group of people to exchange information and insights, reach group decisions through a set of structured exchanges, and collaborate on work projects. With telecommunication links, the group can include people who are geographically dispersed.

At the University of Illinois, students studying to be teachers spend a semester scattered across the state, practice teaching under the guidance of experienced teachers. E-mail, electronic bulletin boards, remotely accessed databases, and computer conferencing allow the students to contact their professors for advice and to discuss problems and solutions with their peers (42).

The advantages of computer-supported collaborative learning include its handling of speech, writing, and even design; the sharing of knowledge and skills; the opportunity for psychological support among similarly situated persons; and considerable flexibility within the frameworks established by the tools. Some users, however, express frustration with the constraints imposed by the frameworks.

Computer-supported collaborative learning could play an important role in school-to-work transition systems by:

- linking the workplaces with the schools;
- helping the partnerships in their planning activities and allowing them to remain in contact between time-consuming meetings;
- helping school officials and teachers coordinate with the workplace supervisors and mentors;
- allowing students in the workplace to access the various resources of the school;
- permitting school staff to monitor students' progress with fewer trips to the workplace; and
- allowing students to take work-based learning assignments far from school, while remaining in contact with their teachers and peers.

The evaluations of computer-supported collaborative learning suggest that it helps the students see things from multiple perspectives, builds their interpersonal communication skills, and lends intellectual and emotional support. The technologies overcome the constraints of time and place that are inherent in face-to-face communications, but they do not convey the power of direct human contact (15). According to some recent studies, exchanges that promote individual learning in a group may not necessarily produce the best group performance (49).

Telecommunications technologies are rapidly being commercialized. Only a few groupware and collaborative design tools are on the market, but others will follow and their evolution is expected to be swift (31).

Computerized Simulations

Computer simulations range from simplified representations of reality to realistic synthetic environments that envelop the user with visual, auditory, and kinematic stimuli. Some are designed to be used by one person at a time; others can be used by groups, even with participants thousands of miles apart.

Classroom Inc. has prepared simulations of a bank, a hotel, and a medical center that introduce middle-school and high school students to the world of work and reinforce their academic skills. In the Chelsea Bank simulation, three or four students are trained as a team in the bank procedures for a teller. Then the team works as a bank teller in eight scenarios of problematic transactions, including a sweet old lady wanting to deposit a post-dated check, a derelict wanting to cash a large check, a friend of the teller wanting a small favor that violates bank procedures, and a rude customer giving the teller more cash than is recorded on the deposit slip. The team must choose among four possible responses to each scenario, and anticipate the consequences of the choice for the customer, the bank, and the teller. Then the team is debriefed about the correct choice and the likely consequences of each possible response. After mastering the teller scenarios, the team works as a customer service representative in seven more scenarios. Selecting the correct responses requires comprehending and applying the bank procedures, making simple computations, understanding the service and business aspects of banking, putting aside personal concerns when appropriate, using critical thinking skills, applying high ethical standards, and engaging in problem solving. Working through the full simulation takes about twenty 50-minute periods, but a number of related research, writing, and computational assignments can be added (11).

Caterpillar Corporation has developed an earth-moving equipment simulator that includes a real steering wheel, gearshift, levers, pedals, and other controls. The visuals are computer generated and provided by a head-mounted display that is worn like a helmet (65).

The general advantages and disadvantages of simulations are discussed in chapter 4 in the section on the "settings" of work-based learning. For computer-based simulations, research has found that students with a naive conception of the simulated phenomena and those who learn best in a well-structured environment tend to flounder and become frustrated (15). In remotely connected group simulations, participants become less inhibited than in face-to-face groups; shy people communicate more and risk "dumb" questions, but politeness also declines (59). Moreover, some users become addicted to computer simulations (8,63).

The Office of Technology Assessment recently examined virtual-reality technologies for combat simulation and concluded that the advances have been rapid, costs have been cut by about half every two years, and the products of military investments have numerous commercial applications (65). The challenges that were identified by OTA included inadequate telecommunications infrastructure for distributed simulations, difficult and time-consuming preparation of the software, and the need for improved visual displays.

Gamelike simulations that rely on text can be developed at modest cost. Those that create realistic visual and audio effects are expensive to develop, and those that add kinematic effects are still experimental. Gamelike simulations are already available on the Internet, but dialing up immersive simulations will require major advances in telecommunications technologies (15).

Simulations for widely used skills, or ones whose traditional development involves considerable risk or expense, are likely to evolve rapidly during the rest of the decade. Smaller or less lucrative markets will probably experience less progress until advances in "authoring" tools reduce the costs of developing the software.

Business Applications Software

Perhaps the most dramatic advance in computer-assisted work-based learning is a result of the business world's rapid switch from expensive mainframes to inexpensive microcomputers for word processing, typesetting, database, spreadsheet, computer-aided design, and other business applications. A computer that 15 years ago cost $500,000 and used $50,000 worth of software can now be duplicated for a few thousand dollars. Fifteen years ago it could cost $100 per hour for a student to practice using a mainframe software package; now it costs less than $1 per hour to practice with more powerful software on a microcomputer. As a result, schools and colleges can easily afford to give students an introduction to widely used business application software packages, and employers can easily afford to have the students practice and improve their skills in the workplace.

Most business application software now comes with computerized tools to help people learn how to use the program. These include computer-assisted training, help systems that explain how to execute specific functions, and the ability to undo one or more steps when things go awry. Microsoft Word, in a bid to win over WordPerfect users, prepared a help menu with WordPerfect terminology that retrieves explanations of how to execute the same functions in Word.

"Some students have taught themselves to use software that their supervisors do not know how to use."—Researcher's observations at a worksite (67).

Although these tools are welcome and occasionally have a clever twist, they have rarely made use of the sophisticated computer-assisted learning technology that is now available. The computerized "tutorials" that accompany the software generally do not have the "smarts" of the intelligent tutoring systems described earlier. The help mechanism usually requires selecting the correct term for a desired function (which is sometimes unknown to the befuddled user) instead of allowing the user to specify a term and having the machine automatically access the corresponding function. In addition, the "undo" functions sometimes apply only to the last command or two, while mistakes often are not apparent until after several commands have been executed. Despite these shortcomings, further progress in the learning aids built into business software is likely. New companies continue to introduce add-on products, and the big developers continue to incorporate more assistance.

The Future of Technology-Assisted Work-Based Learning

A recent OTA report documented that schools have been slow to incorporate technology-assisted learning (64). There are at least three forces that are likely to accelerate the adoption of computer-based learning in workplaces. First, computers are now common throughout many workplaces. Second, today's $1,500 microcomputer has about five times the speed, RAM, and hard-disk storage capacity as a similarly priced microcomputer of just five years ago. Third, learning software is evolving from simple computerized textbooks to a variety of more sophisticated tutors, hypermedia with navigators, collaborative learning systems, and simulations.

Computer-assisted learning is not a magical guarantee of learning success. Some software has given visual effects precedence over content; some alleged "artificial intelligence" has been closer to artificial stupidity; and some software is "buggy" and operates improperly. Nevertheless, the advances have been impressive and are likely to continue.

CONCLUSION

There is little evidence concerning the relative effectiveness of the five identified work-based learning processes, but each appears to have different advantages and disadvantages. Guided experiential learning requires flexibility on the part of the guide, but can help the students hone their experiential learning strategies for life-long use. Mentoring is time-consuming, but provides the students with comprehensive support, assistance, and feedback over a sustained period of time. Work-group learning is sometimes too subtle or overwhelming, and low-performing groups can teach students the wrong lessons, but this learning process requires few additional resources and conveys essential knowledge and skills that often are not taught by other means. Normal workplace instruction often conveys facts and simple procedures efficiently, whereas cognitive apprenticeships are a time-consuming but potentially powerful means of developing complex intellectual skills. Finally, technology-assisted learning is sometimes inflexible and expensive, but it has produced some dramatic results and hardware costs are declining rapidly.

Extensive research has shown that most people, both adults and youths, are not adept at transferring skills learned in one situation to different situations (16). This is good reason for locating students' training for work within workplaces, but the lack of transfer also ominously suggests that no preparation will be adequate for a rapidly changing world, and that career success will require continuous learning. Because learning skills, like other skills, do not generalize well (16), it appears desirable for students to become adept with many processes and contexts of learning.

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