Tomorrow's Classroom — The Changing Focus in Computer Education

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Part I: The Evolution of Corporate Educational Services

Digital Equipment Corporation today is the world's second largest manufacturer of computers. One of the challenges Digital has addressed is the computer education of both its customers and its employees. Digital's Educational Services Department has grown in relationship to the increasing importance of providing computer training that is cost efficient and easy to use.

No technology is developing more rapidly than the computer — it has changed our interests and our ways of thinking. In this process, the ways we learn about computers have also been revolutionized. When Educational Services began in the 1960s, the task was to impart detailed, operational information to those involved in the development and manufacture of a computer. At that time, computer users and service people were as elite a group as those who designed the computer. Traditional teaching methods, lectures delivered in a central classroom facility, were successful. Educational Services had five classrooms and two teaching supervisors, one responsible for employee education, the other for customer education.

Necessary to look at role the computer could play in learning

With the development of simple, fast, and inexpensive minicomputers and the explosion of the numbers of people who use them, the educational needs of the industry changed. No longer did everyone who used a computer need to understand the details of how it worked. The great numbers of people who used and serviced computers did not have a background in electronics. They needed to learn fundamentals quickly and only the details necessary to do their job.

In addition, the costs of supporting a central training center to deliver lecture courses became prohibitive. Travel and housing costs were increasing, and the expense of taking time away from the job for training became important. Offering lecture training for everyone was inefficient.

It became necessary to really look at the role that the computer could play in learning and to consider what possibilities the future offered. Only with this approach could a productive direction for computer education be found. Training is now moving out of the classroom to meet the student. In 1982, Educational Services Department provided over 100,000 weeks of training to over 50,000 customers and 28,000 employees. Educational Services has a professional staff of 1700, 400 of whom are instructors delivering courses in educational centers.

Educational Services takes an engineering approach to education, creating teams that develop courses, determine how the courses are to be taught (delivery methods), and design evaluation tools. A team consists of subject-matter experts, writers, editors, media specialists, producers, educational psychologists, programmers and instructors. They use a systematic design procedure for developing a course that begins with a description of the job to be learned and an analysis of what specific skills must be mastered for job success. The team works to ensure that the course teaches those skills and effectively reaches the specified audience.

While the growth of Educational Services can be seen as tangible evidence of the need for computer education, we realize our success comes from working to increase the producitivity of training, by reducing costs and increasing ef-

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fectiveness. Now the new, more sophisticated delivery methods being developed by Educational Services promise more effective training at even lower cost. Computer-based interactive video instruction and computer-based instruction (CBI) are two examples.

Computer-based interactive video is system-based education enhanced by audiovisuals, a combination of computer technology and laser disc technology. It is designed to be used locally, allowing students to complete a lesson at their own pace, with the capability to repeat at will. Studies done for the National Science Foundation show that retention rates increase dramatically with the use of computer-based interactive video; psychologists attribute that increase to the reduced anxiety of self-paced learning and an instruction method that is not threatening. The corporation is currently using computer-based interactive video to train 250 of its field service representatives in the repair and service of Digital computer systems.

Computer-Based Instruction (CBI) is training that is delivered with the computer. Since about 62% of all personal computer buyers have no computer background, the goal is to make the computer "transparent" to those users, so that when they turn the computer on, it tells them how to use it. Educational Services developed the system overview ("Do Me First") CBI for the corporation's Professional Computers — software that instructs the first-time user in the capabilities of the computer.

Today's business climate has also made the move toward new educational technologies a necessity. Educational Services' growth is part of a nationwide expansion of business investment in industrial education. Changes in the American economy have changed educational needs. As the economy moves from a manufacturing-based to a service-based economy, as the baby-boom labor force ages, and as technological changes outpace our ability to assimilate them — so the need for extensive training and retraining increases.

The prospect of lifelong retraining is real these days, and not just for the displaced blue collar workforce. The half life of an engineering education is five years. Today, industry is not paying for experience, it is paying for current technical knowledge. As a result, companies are now investing more in their people. American industry is spending close to $40 billion a year on training, the U.S. government about $20 billion — and training needs are still not being met.

Today industry is paying for current technical knowledge

The need for continuing education in the computer field can be easily demonstrated. For business, the benefits of training are twofold, increasing employee effectiveness and remaining competitive. Educational Services is working to magnify the benefits of computer education by maximizing the efficient use of the student's time while providing high quality, relevant education. Through the increased use of technology to individualize instruction we are working simultaneously to decrease the cost of each instructional hour.

Part II: Educational Technology Applications in Training

The Decentralization Dilemma

Digital's Educational Services believes that the future of industrial training lies in decentralization — the delivery of high-quality training locally. Our investment in this approach is based on the following set of conditions that are true not only for Digital, but for many large corporations.

- More job-specific training is needed to work in modern industry.
- Workers need more on-the-job training to constantly upgrade their skills.
- Increased numbers of people need such training.
- Industrial training programs provide a greater percentage of overall education.

- Employees are geographically dispersed.
- The cost of delivering training in central classrooms has become too high.

One of the first solutions explored by Educational Services when faced with the need to decentralize was to take the instructor to the student, either by periodically bringing instructors into an office or by establishing small training centers near students. When the number of training locations is small and there are many people to be trained at each location, this can be cost-effective. In many cases, however, bringing in instructors is unsatisfactory due to scheduling problems. Employees who need training must "mark time" for weeks or even months until an instructor is available. On-site training centers can solve this problem, but they fall short when the skills students need to learn outnumber those that can be mastered by the resident instructors.

Programs must be adapted to individual learning problems

Traditionally, large corporations solved this problem by increasing their commitment to a lecture-based delivery system, establishing training centers at their major sites and supplementing the resident staff with instructors from training headquarters. The high cost of this approach has now caused many corporations to turn to educational technology in an attempt to find other methods for delivering instruction.

We have found that new technologies, such as computer-assisted instruction (CAI) coupled with an interactive videodisc, can be used to deliver quality instruction cost-effectively at a large number of widely dispersed sites, even if only one person needs to be trained at each site. These technologies also allow us to provide decentralized training that is appropriate for widely diversified student audiences.

When Assistance Is Absent

Digital has delivered decentralized training with and without requiring an instructor or course administrator to be present. (An instructor is assumed to be trained in the subject matter being taught, while a course administrator is not.) We have found that course administrators can provide students with invaluable support, even when they are totally unfamiliar with the subject matter. If the administrators are familiar with how the courses are designed and with how they are intended to be studied, they can solve minor problems caused by oversights in course design. More knowledgeable course administrators can also help students solve minor technical problems and tailor their choice of which modules to study to meet their individual goals.

The presence of an assistant is therefore a major factor in a training program's adaptability. When there is no assistance, students tend to go through the course materials in a routine manner, following each instructional sequence exactly rather than adapting the materials to their own learning needs and goals. The path they follow is typically linear, and they seldom review adequately when they get into trouble with advanced topics. To make decentralized training fully effective, programs must be adapted to individual learning problems even when no assistant is available.

Automating Adaptability

The people we train have widely diverse backgrounds and learning goals. Some join Digital after doing similar jobs in other companies, while others have little previous experience. Some study our courses to obtain detailed job skills, while others look only for generalities to help them in planning. Training programs should adapt to the slightly different goals and skills of each student. We currently use three technologies in our efforts to develop training that achieves this goal: *linear video, computer-assisted instruction,* and *interactive video.*

Linear Video

Linear video can be used as either the major source of a course's technical information or as a supplement to information provided in less expensive media such as texts. We use the term "linear video" to refer to all material designed to be viewed sequentially. Students may, of course, stop a tape, rewind it and replay video sequences, but these actions are a minor subset of the control allowed by interactive video devices such as the videodisc. Adaptability in these courses is achieved by clearly communicating break points and making sure students are aware of their options.

Our video materials are always supplemented with written or laboratory exercises. The extent to which students complete these exercises depends heavily upon their learning goals. If they are studying for details, they will typically spend far more time doing exercises than watching the video. If they are studying for generalities, they may view the video material straight through in one or two sittings.

No matter how complete we make the supplementary materials, the interaction between students and video-based courseware will always be predominantly one-way. Students must evaluate their own work and determine that they are "missing something" before they review and try to strengthen weak concepts. Evaluating one's own work is a difficult task itself, but reviewing linear video materials to discover what one missed is even more difficult. In many situations we need a way to deliver decentralized training that is more adaptive.

Computer-Assisted Instruction

Much of the adaptability we seek can be provided by CAI. CAI allows us to query students and thus establish a two-way interaction between students and the courseware. This "dialog," as Alfred Bork has called it, is essential to determining when and how the training program should adapt to the learner.

Our CAI materials have several levels of adaptability:

- The course pace can be controlled easily because information remains on the screen until students make some kind of response to tell the program to go on.
- Students can move quickly and easily to any section of the materials. This is done by selecting options from menus.
- Students are free to go on to more advanced sections or to review sections already studied at any time. There is no need to step through one lesson to get to another as one must do with linear video.
- A number of learner aids are available, such as help with operating the CAI system, advice on how to answer a question, and an on-line glossary.
- The system monitors student progress and can detect when additional instruction is needed. In these cases it can recall an appropriate learning sequence or exercise and, if needed, direct students to supplementary sources (including an instructor or course administrator.

Much adaptability can be provided by CAI

CAI has definitely brought us closer to our goal of automated adaptability, but at the expense of some presentation capabilities. While the graphic quality of today's CAI systems is indeed excellent, it cannot reproduce photographs and live action sequences with the clarity of standard video. Much of the material we teach requires video-quality images, particularly courses on hardware maintenance. To satisfy this need while maintaining the level of adaptability provided by CAI, we have begun to produce courseware that takes advantage of the technology of interactive video.

Interactive Video

We use the term "interactive video" to refer to video systems that are computer controlled and allow any part of the video program to be accessed at will. A number of video tape systems exist that exhibit these qualities, but their access time is considerably slower than that of videodiscs. Given the additional features available through optical videodisc technology (such as crisp, clear still frames; single stepping; fast, accurate selection of individual frames; continuously variable slow motion; and inexpensive reproduction in high volumes), we believe that the development of interactive video systems will proceed with videodiscs rather than video tapes.

Digital has developed an interactive video system for employee training that combines the best qualities of both computer-generated and video displays. This system fully integrates video with CAI by allowing both images to be displayed on a single screen. In addition to allowing two separate "windows" into the courseware, video images can be overlayed with computer-generated visuals and text. This capability has given rise to a number of new presentation techniques. Some of the techniques we have experimented with so far include:

- Highlighting specific components in shots of a complex device by outlining or pointing to them,
- Drawing hidden data paths to show how pictured components interconnect,
- Adding orientation information at the top and bottom of the screen,
- "Lighting" different control lights on a control panel while describing their meanings,
- Providing student control of the display of a video sequence,
- Using composite video images as menus and allowing students to indicate their choices by moving a cursor to different areas of the image or by simply touching the screen,
- Creating exercises that ask students to identify specific components by pointing to them,
- Correcting slightly erroneous video information by blanking out the incorrect screen area, overwriting the error, or simply displaying explanatory text, and
- Adding foreign language subtitles to standard video sequences.

The development of interactive video systems will proceed with videodiscs

The level of adaptability made possible by this system far exceeds that of either linear video or CAI on its own. For example, students might be introduced to a new piece of equipment with a video sequence. If later evaluation then shows that a student does not understand how a particular component works, part of the video sequence might be repeated with the component in question highlighted via computer overlays and additional computer generated graphics added to enhance the presentation. Alternatively, computer graphics might be used to diagram the component and its parts rather than repeating the video. These techniques and the many other possible variations allow interactive video to be extremely adaptable to a large number of student backgrounds, abilities, and learning styles.

It has been found that the use of interactive video has significantly reduced the time required to train our employees. In addition, since training is delivered locally, not only are per diem and travel expenses eliminated, but training is no longer a one-shot effort. The course is always available for review.

Sophisticated Software

The discussion thus far has concentrated on the hardware side of educational technology. It is appropriate to focus on hardware first, because the term "educational technology" usually conjures up images of slide projectors, film loops, video tape recorders, and other assorted gadgets. The advent of computers, however, has created an increased urgency to focus educational technology efforts on software tools.

The control of sophisticated hardware requires sophisticated software. Our experience has convinced us that the production of effective CAI for industrial training is accomplished most efficiently through the use of specialized software tools tailored to the needs of CAI. In particular, we advocate CAI authoring systems that are strong in their abilities to judge student responses

continued on page 108

and to design and modify screen displays seen by the student. Part of our reason for listing these as important features is our frequent need to present to a student a display identical to what he or she will find on an actual piece of equipment and to simulate its response to various student actions.

While we have used several tools in the past (such as code generators and simple interpreters) we are presently working on an expanded CAI and screen-design language that also incorporates modern principles of structured programming. This language is designed to allow us to offer CAI on all of Digital's products.

If we really are to achieve the goal of decentralized programs adaptable to different student backgrounds, abilities, and learning styles, we must have as firm an understanding of how people learn as we do of how machines can teach. Research in cognitive science is beginning to give us a number of principles to guide course development, and new software tools are making CAI more effective, but the task of creating such sophisticated courses is still formidable.

One of the most promising developments in this regard is the recent emergence of artifical intelligence (AI). AI is not a new technology, but it is one that has seen little application outside of experimental laboratories due to its need for extremely large computing resources. Recent developments in both hardware and software have now made AI practical as an instructional tool even on some microcomputers.

AI applications to CAI usually require a formal *representation of the task* to be taught, an explicit *model of the student's abilities,* and a set of *guidance rules* to relate the two. The formal representation of a task might be a detailed list of each component skill needed to master the material being taught. The model of the student's abilities can then be a representation of the student's knowledge task analysis and a history of the student's interactions with the CAI program. These two components, taken together, yield a clear picture of what the student does and does not know. The guidance rules then relate specific student states to the various teaching operations (lessons, exercises, and tests) that the CAI program can perform.

The keys to these AI components are that each one typically requires a very large number of variables and extremely powerful computing resources to appear truly "intelligent". While conventional programming languages might be used to implement such complex software, the task is considerably easier (and more resource efficient) using the sophisticated tools and techniques now emerging from the AI community. The hope of AI is that teaching programs can be built with as much technical knowledge as subject matter experts, and as much teaching knowledge as psychologists and educators.