CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

Microcomputer/Videodisc System for Construction Education

Hossam El-Bibany and Boyd C. Paulson, Jr.

TECHNICAL REPORT
Number 47

April 1991

Stanford University

If you would like to contact the authors please write to:

c/o CIFE, Civil Engineering,
Stanford University,
Terman Engineering Center
Mail Code: 4020
Stanford, CA 95305-4020

Microcomputer/Videodisc System for Construction Education

By Hossam El-Bibany[1] and Boyd C. Paulson, Jr.[2], M.ASCE

Abstract

This paper addresses the need to improve the flexibility, productivity and effectiveness of educational methods, especially in teaching subjects involving large-scale phenomena that do not lend themselves well to lectures or laboratory experiments. The central part presents a multimedia educational system for teaching construction equipment and methods. It describes the main objectives in developing this system, and illustrates its approach with one of the prototype modules that deals with earthmoving scrapers. The educational results are mentioned, along with suggestions for cooperation among universities to make more systems of this type widely available. The description of the development methodology also comments on its limitations, but these are rapidly being overcome with improved standards and availability of similar tools on other computers.

Introduction

One of the inescapable educational phenomena today is the contrast between the image of the seemingly bored undergraduate student sitting in the back of a typical engineering class, and that of the same same student a few minutes later—every muscle tensed, adrenalin flowing, face mesmerized with excitement—hooked on a videogame machine over at the student union! What is it about that machine that is so interesting? How many professors would still be employed if students were expected to keep inserting quarters to keep traditional lecture classes going? Can the technology behind the videogame machine be redirected to excite the student and channel that same high energy and motivation into higher educational pursuits? Can professors improve education by incorporating that technology into teaching pedagogy? What other benefits might arise from the more productive application of computer-based video technology?

The advanced videogame machines found in game parlors are among the most familiar examples of multimedia computing technology. They employ high-speed microprocessors and ample memory to generate dynamic graphic images and dramatic sounds, and to retrieve realistic TV images from video or optical discs hidden inside. The user controls are simple, consisting mostly of one or two joy-stick levers and a few buttons (plus the all-important coin slot), yet the high-speed simulations that these machines create challenge the brightest student minds. Even the observers that often surround the player usually are held in rapt attention, and can hardly wait to start emptying their own pockets. Are educators missing something here?

---

[1]Research Assistant, Dept. of Civil Engineering, Stanford University, Stanford, CA 94305-4020.
[2]Ohbayashi Professor of Engineering, Dept. of Civil Engineering, Stanford University, Stanford, CA 94305-4020.

While this technological revolution has been underway, higher education has been facing problems of declining productivity relative to other sectors of the economy. Legislators and parents are resisting the growing costs that have resulted. Teaching methods predominantly remain based on lectures where a classroom instructor presents material to students in a linear sequence. While lectures may be supplemented by overhead projectors to reduce the time consumed writing notes on the chalkboard, and copy machines have helped free students to pay attention to the lectures rather than spend all their time frantically copying notes from the board, this method of teaching has still changed little over several centuries. All students in a class receive the identical body of topics selected to represent the subject being taught, and they receive it at the same pace regardless of abilities. While one can truly admire the give and take of an outstanding teacher interacting with—and indeed inspiring and motivating—students in a small class, the method has its limitations with larger groups.

Some courses inherently will be limited in the academic environment regardless of the quality of instruction, notably those dealing with large-scale physical phenomena as well as conceptual topics. An applied subject like construction equipment and methods is particularly difficult to teach adequately in the classroom, even though this is the typical way it is presented. Textbook pictures, movies and slides help to convey some of the scale and complexity of the subject, but they are passive rather than active media from the student's perspective. Field trips give an opportunity for more direct observations of the resources and questioning of the parties involved, but still are limited in terms of actual participation. This subject could be enhanced greatly through hands-on experimentation, yet owing to cost, safety and accessibility issues, few students have a chance for such experience. They thus must do their problems and examinations using fairly abstract notions of the physical world with which they are dealing.

Technology now exists to significantly alter the paradigm for teaching while simultaneously improving the productivity, quality and flexibility of the process. Popularly known as multimedia computing, it enables students to experiment more actively with their subject, and better personalize the learning experience to their own abilities, needs and interests. While this simulated environment is still not the best substitute for hands-on experience with full-scale phenomena in the real world, it certainly has advantages in terms of cost, time and safety. It also facilitates the integration of theoretical knowledge with empirical knowledge in the learning process.

This paper will describe one experience in integrating multimedia computing technology into teaching a course on construction equipment and methods. While presently it is only a partial replacement for the traditional teaching methods that are still used in the course, the results thus far show that it is effective and has the potential to become the dominant method of teaching. The instructor's role could evolve to what has always been one of the best modes of education, but hitherto a prohibitively costly one for all but the most elite classes, which is that of tutor.

The Course

CE 145–Construction Equipment and Methods is an undergraduate course at Stanford University, and is not unlike its counterparts elsewhere. In 30 hours of lectures, supplemented by a standard textbook (e.g., Nunnally 1977 or Peurifoy and Ledbetter 1985) and a *Caterpillar Performance Handbook* (Caterpillar 1989) for reference, plus problem sets, examinations and field trips, it covers basic types of construction machines, plus some of the engineering mechanics and economics that enable one to analyze their production and costs. Like other traditional courses, the material is limited to the selection that the instructor thinks most suitable for simultaneous conveyance to each member of the class, and the pace is dictated by the schedule of lectures.

The development of multimedia course materials for CE 145 began in the Fall of 1988 with a module for teaching the section dealing with scrapers. It was introduced in the Spring of 1989, and development and introduction of new material has continued since. This paper will focus on that experience, but the approach can apply to a wide variety of other courses. At Stanford, similar applications now in use range from aircraft design to anatomy to foreign languages. Candidates in civil engineering are found in all specialties, including geotechnical engineering, hydraulics, environmental engineering, transportation and structural engineering. Even management-oriented subjects like contracts and specifications could capture real cases in multimedia form and involve students in the decision processes as they happened.

What is Multimedia Computing Technology?

The basis for multimedia computing is a powerful and highly interactive microcomputer which has its own strong software capability to support animated graphics as well as static text and graphic images. This computer is supplemented by a device, usually a video or optical disc player, that allows large amounts of video material to be presented when called from software; video segments can be shown either in a separate window on a large computer screen, or on an adjacent monitor. Sound is commonly incorporated, both from the soundtracks accompanying video segments, or by direct synthesis of voice, music or other sounds in the computer itself. Students normally interact with the software using a keyboard or mouse, or sometimes via a touch-sensitive CRT screen. Figure 1 shows a schematic diagram or a typical multimedia computer setup.

Terminology. Like any new subject, multimedia computing has acquired some of its own terminology and uses of familiar words. Common computer terms, such as mouse, CRT, window, etc., are assumed here, so the list is more focussed on graphics-based multimedia software. A few terms used in this paper are as follows:

icon—a small graphical symbol, typically used to show choices or options that the user can select with a keyboard or mouse.

click—the action of using a mouse (or equivalent) for positioning the cursor over an image on the screen and pressing a switch or key to select the function or give a response that corresponds to that image.

button—an icon that can be clicked, using the mouse, to perform a particular function.

card—a single computer screen window displaying information for the application. A complete application may use hundreds of cards.

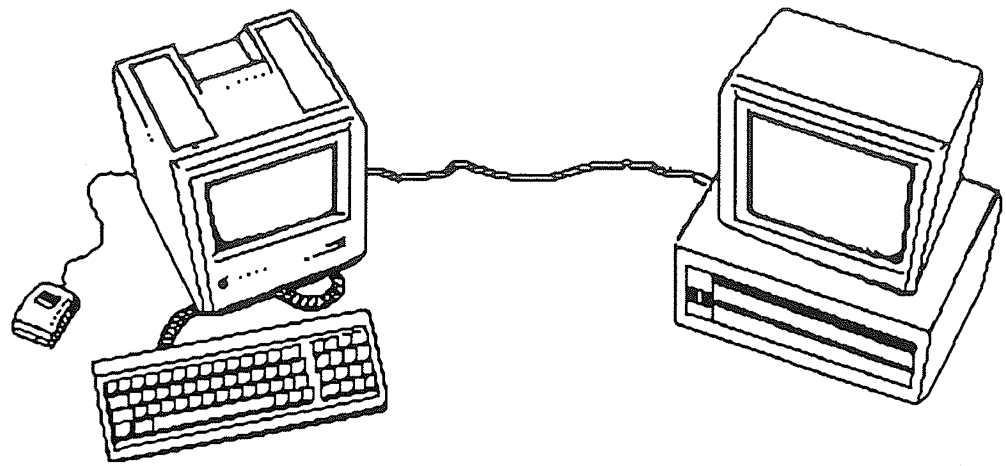

Figure 1. Components of a typical multimedia system

Objectives

The main objectives that motivated us to develop this system as an aid to teaching construction equipment and methods were to:

- Improve the productivity and effectiveness of teaching by shifting the role of the instructor more to that of a tutor rather than a classroom lecturer, and by offering to the student greater flexibility in content, pace and sequence for learning new material.
- Provide students with a closer look at the equipment and methods of construction, and give them the hands-on ability to manipulate and analyze what they observe to gain simulated but realistic site experience about the design and application of equipment in the field.
- Reinforce the understanding of underlying theoretical concepts and principles by analyzing equipment operations' productivity using various computer-based media.
- Provide on-line computer equivalents for the pedagogic functions of homework questions, tests, experiments and classroom note-taking.
- Build general training modules that can be made public or be exchanged between different educational institutions.
- Produce a generic shell for course development that will allow a non-computer-expert teacher to add, update and reorganize course material to suit local needs.

The way we went about achieving these objectives might best be shown by continuing on to a description of ConEq, the prototype system that we built. It should be noted, particularly in connection with the last two objectives, that we are now planning to make a generic version of this application—that is, one where the course-specific content has been removed but where examples and instructions are included—so that others can more easily create similar multimedia presentations of their own course materials.

Overview of ConEq

The topics envisioned to be taught by ConEq can perhaps best be seen in the copy of its introductory screen shown in Figure 2. While not all modules shown have been implemented yet, there is provision for the following topics:

- Backhoes
- Trucks
- Scrapers
- Tractors
- Loaders
- Cranes
- Mechanics
- Economics

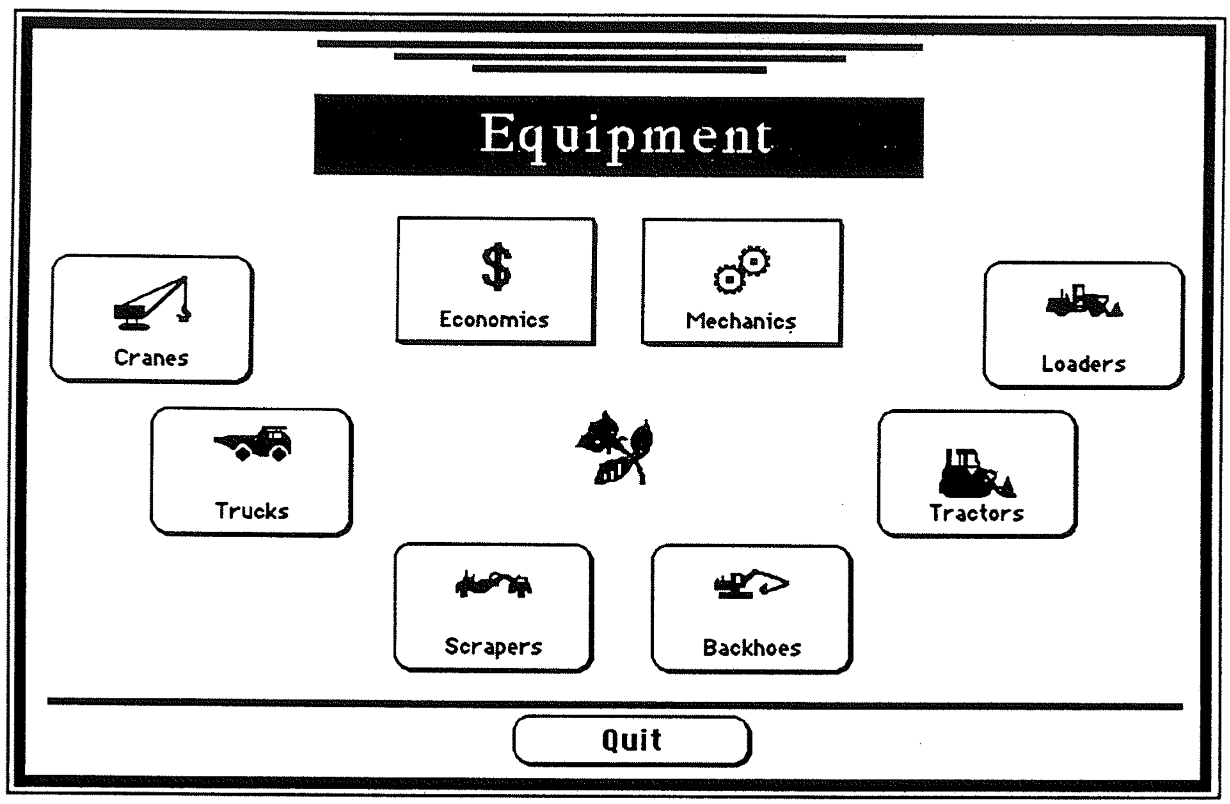

Figure 2. Main menu of ConEq modules

These are the same topics covered in the recent conventional version of CE 145, with the exception of simulation, which is handled by a separate program on the computer. One of the real advantages of such a system, however, is to be able to add more specialized or advanced modules on other topics to enable an above-average student to acquire more than would normally be covered in such a course, or to allow students to explore more deeply topics of particular interest to their own needs. Examples that easily could be added include tunneling machines, paving equipment, dredges, etc. The possibility of cooperative efforts to create and exchange such modules will be explored later in this paper. With such flexibility, courses could be designed, say, to have all students cover a certain core or material, and then select some number of additional topics to meet their own needs and interests. Since the evaluation procedures to perform the equivalent functions of problem sets and examinations can be built into this type of system, this flexibility need involve little or no additional work on behalf of the instructor to prepare and grade numerous alternative assignments and exams.

One can select one of the modules from the menu in Figure 2 simply by positioning the mouse cursor over its icon and clicking. As an example of this multimedia system in action, let us now assume that the student has used the mouse to select the *Scrapers* module for study.

ConEq Scrapers Module

The pilot project focused first on the class of earthmoving machines called scrapers, which have some interesting non-linearities in the production process that can be taught well by the interactive video approach. Scrapers have established an important position in the earthmoving field because they can be self-operating to load, haul and dump materials and they work in a wide variety of conditions. The main instructional objectives of this module are to show the different parts of the scraper, explain how they work, describe various types of scrapers and the differences between them, discuss the variables which influence productivity, explain the analytical and graphical methods for optimizing the scraper's production, and transfer to the student some semblance of the real site expertise needed in equipment operations management.

The first screen that comes up in the Scrapers module is shown in Figure 3. It presents another menu of seven options that can be selected in any order.

While looking at this card, take a moment to examine the general functions, shown as icons on the left side of the screen, that can be called from most cards in the ConEq system.

- The *Help* button summons explanations pertinent to the functionality of the system itself (not the course material), similar to many other software packages. It is intended to prompt the user for either general system help or specific card help.
- The *DoorOut* button illustrates this system's ability to call upon other software applicable to the course, such as a simulation program, a spreadsheet, or a database, whenever the student wants it. This option asks the user to choose from a list of available software, with some recommendations about what is applicable at the current position of the user in the system. For example, it the user is in the Scrapers module, the system would recommend

a simulation model for a scrapers earthmoving operation. When the user is done with that model, the system resumes with the ConEq module at the point where the user left off.

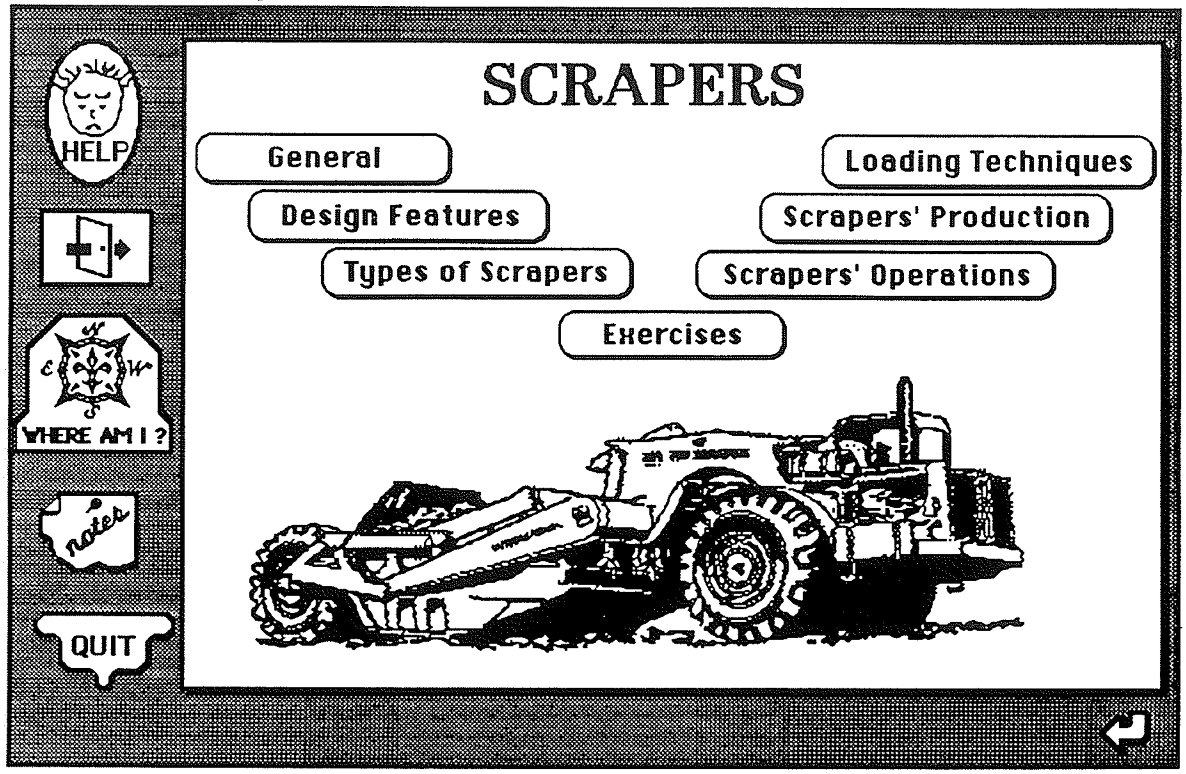

Figure 3. Menu of topic options in the Scrapers module

- The *Where Am I?* button calls up an hierarchical map of the system to enable a student who is lost in its complexity to become re-oriented within the overall structure of the module. Figure 4 shows the map for the Scrapers module. The user has the freedom either to go directly back to where he or she came from, to go to another part of the tutorial by clicking on its icon in the map, or to obtain more details on each part of the module by clicking on the "D" appearing on each card icon. Clicking "D" takes the user to a detailed card-by-card tree-like layout of this part of the module (Figure 5). In Figure 5, each card is iconized and gives the user information on how much time (accumulated over multiple visits) he or she spent studying it. The user can thus see if any card was skipped and can jump directly to it by clicking on its icon.
- The *notes* button serves the function of a notebook a student brings to class, but in this case it enables notes to be typed in directly and saved on the student's own diskette for later review on-line or for printing, as desired. Clicking *notes* activates a text window in which the user can type notes pertinent to the card currently being displayed.

- *Quit* leaves this program after saving information about the student's progress and performance in this session.

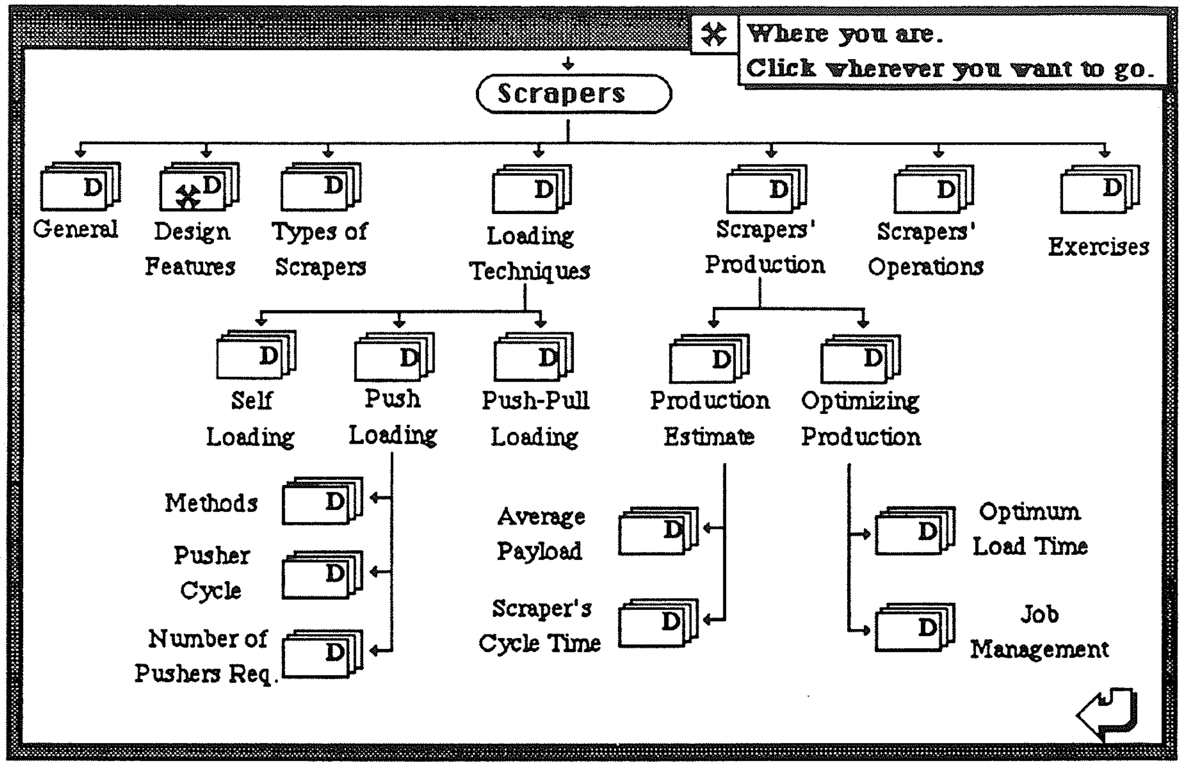

Figure 4. The Scrapers module hierarchy

Organization of the module. One of the main problems in developing training modules is providing flexibility to take different user needs into account. The main restriction that HyperCard imposes on the developer and the user of the system is that it only displays one card (screen) at a time. The different cards can be rearranged or browsed through in any logical order.

We studied different categories of operational details pertaining to scrapers and organized the material in a corresponding hierarchy. Figure 4 showed the hierarchy for the Scrapers module. The system is designed to either lead the user through the hierarchy in a logical manner, or to freely provide access to any card.

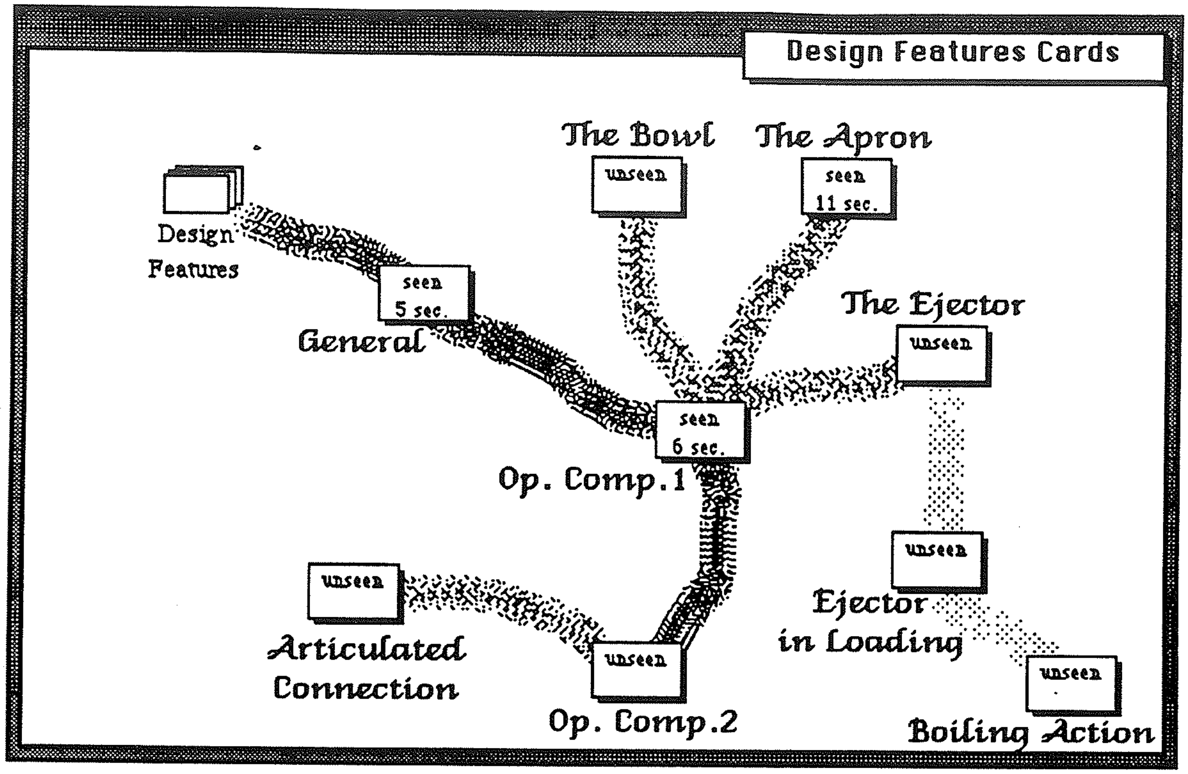

Figure 5. A detailed (card-by-card) sub-hierarchy of the *Design Features* section

Screen layout for flexible control. Figure 6 shows a typical screen layout in the Scrapers module. The general layout around the borders of this screen is consistent with others in the ConEq system. The screen is divided into two main control areas in the background borders, plus the main field for displaying information specific to the current topic. These three functional areas are described below.

Left strip - general utilities. This area of the background consists of five graphic buttons appearing on every card of the system (Help, Quit, etc.), as described earlier for Figure 3.

Lower strip - control. The buttons in this background area allow the user to move to other cards and to control the videodisc player. The bent arrow button takes the user to the card one level back *up* the hierarchy. (We later will see left and right arrow buttons that move the user "horizontally" back and forth in a series of cards at the same level, such as those in Figures 10 and 11.) Taking the user to only one card level higher in the hierarchy is helpful in maintaining his or her location in the hierarchy.

The videodisc controller appears in the lower middle part of cards, but only when there is at least one videodisc segment to watch. The controller allows the user to play the segment forward or backward in slow, normal or fast motion, as summarized in Figure 7.

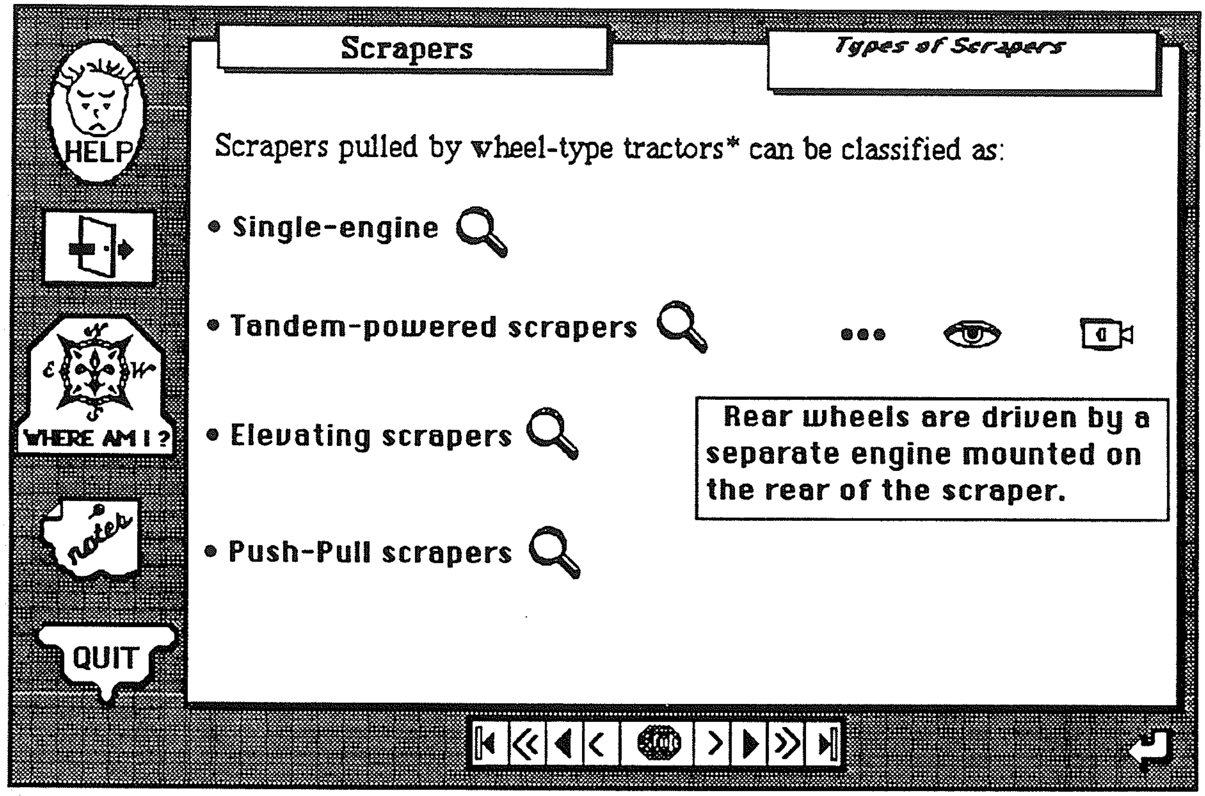

Figure 6. Typical screen layout

Main field. The large central white area in Figure 6 is the topic-specific explanation area where text, graphics, control and detail buttons appear. Two different types of control buttons in this example play video segments (clicking the *camera* icon shows about 30 seconds of video of a scraper in action) and still frames (clicking the *eye* icon here will display a picture of a twin-engine scraper on the TV monitor or window). The *ellipses* button ("...") displays subordinate text comments in a small window on the same card (the note about the rear wheels of a tandem-powered scraper in this case). The *magnifier* button takes the user to a different part of the tutorial (usually to cards further *down* in the hierarchy for more detailed information). Active or animated graphics might also appear in such a card. A few of these facilities will further be explained below.

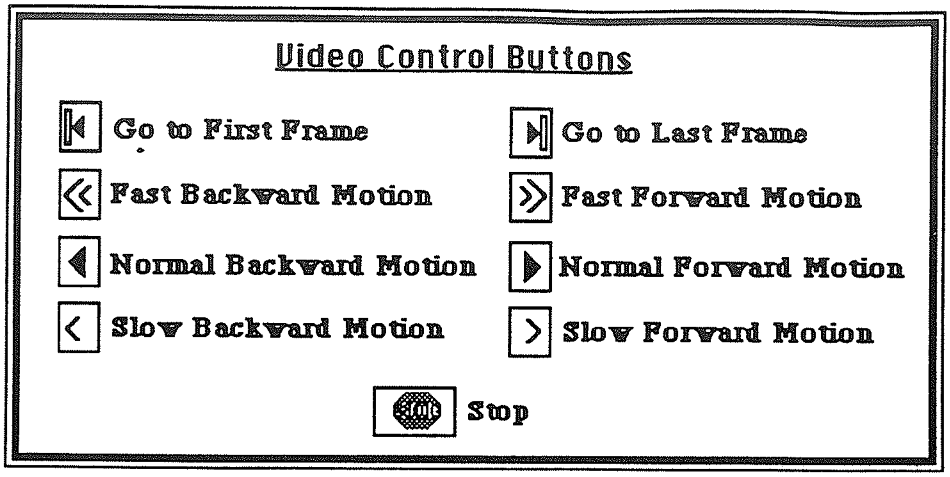

Figure 7. Video control buttons

Media design. In designing the presentation media, the main goal was to develop an interactive, mentally stimulating module (i.e., the user must think and respond on-line) while giving the user as much simulated site experience as possible. For each part of the module, we tried different media, and the best results were integrated into the final module.

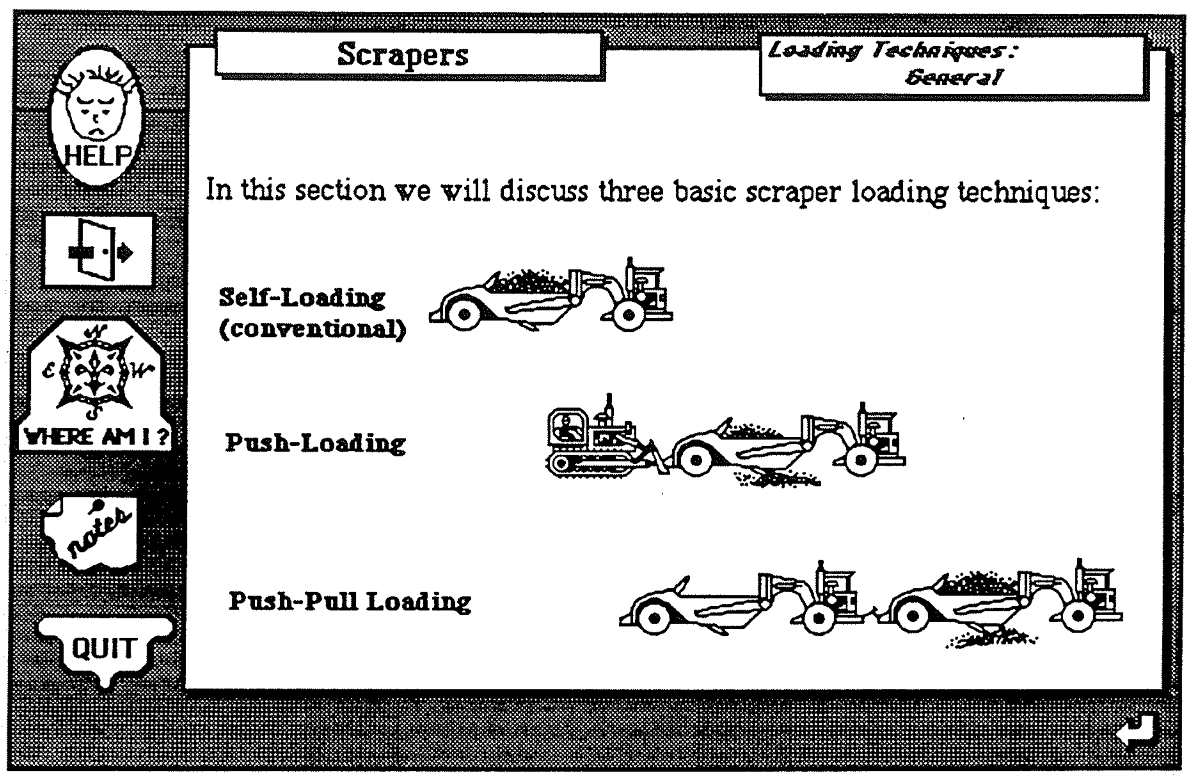

Figure 8. Use of static graphics both for explanation and as a menu

Text. Text is used mainly for explaining issues related to graphic or video segments, and for user responses to narrative questions. To increase the student's interaction with the system, some explanatory text is presented as questions, where the student has to think and come up with tentative answers before seeing the right answers. The answers can be collected automatically for the instructor's evaluation of the student's understanding.

Static Graphics. Static graphics show more details of (1) certain parts of the machine, and (2) productivity curves for optimizing the scraper's production. They were created using drawing and painting software and digitizing techniques. Figure 8 shows an example. In this case, clicking on any of the three pictures will take the user to additional cards and video providing detailed information about the indicated loading techniques.

Animated Graphics. Animated graphics present different push-loading techniques and illustrate the pusher cycle. They were created either by displaying different graphics cards in the required sequence, or by adding pieces of graphics in the required sequence on the same card. In one example, the scraper and pusher move on the screen while the text below changes to explain each step of push loading. Figure 9 is one card from an animated sequence that explains each step of back-track push loading.

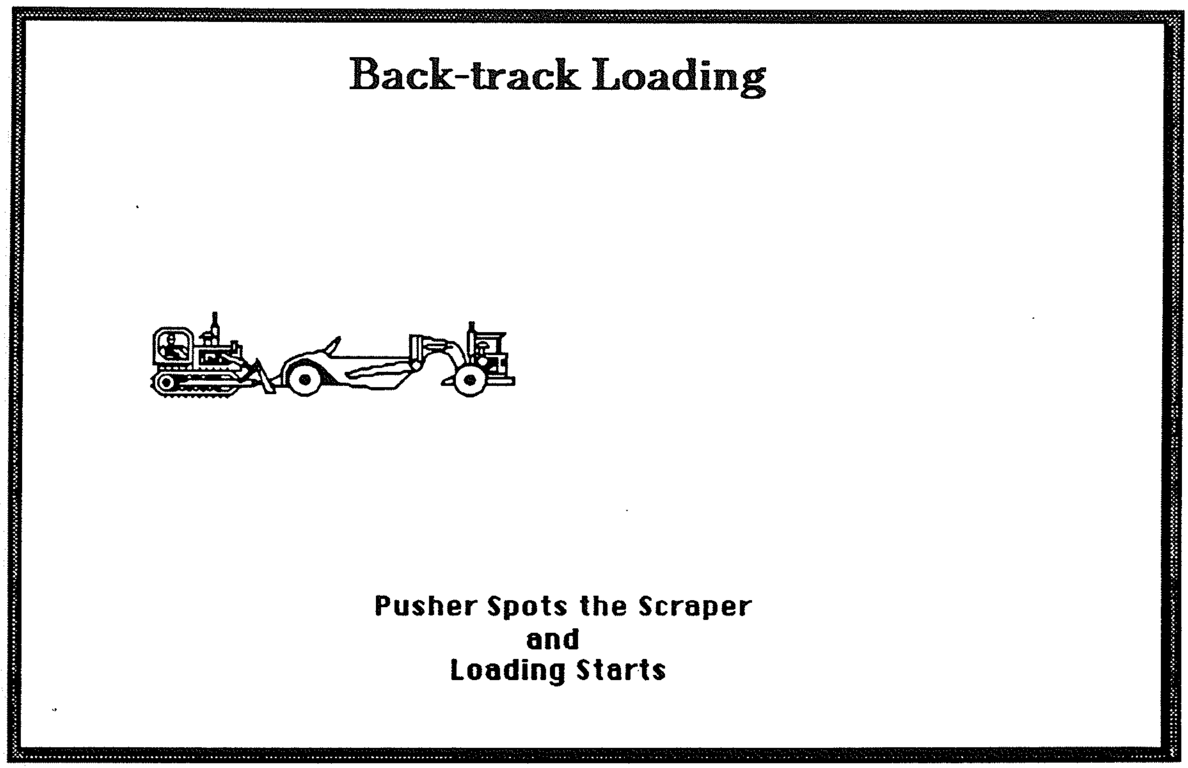

Figure 9. Use of animated graphics with explanatory text

Active Graphics. By active graphics, we mean graphics that respond to a user action upon the graphics. The user can act by clicking on different parts of the graph, or by clicking on different action buttons while the graph is undergoing change. Figure 10 is an an active graph on which the student clicks on the point on the curve that he or she thinks corresponds to the scraper's optimum loading time. The main objective of this graph is to transfer to the student the idea that the optimum load time is obtained graphically by drawing a tangent to the load-growth curve from the scraper's balance-of-cycle time (ignoring the pusher for now). The card automatically draws the lines from the balance-of-cycle time to the point on which the student clicked, until the student finds the optimum load time, at which time it also displays the note about the tangent.

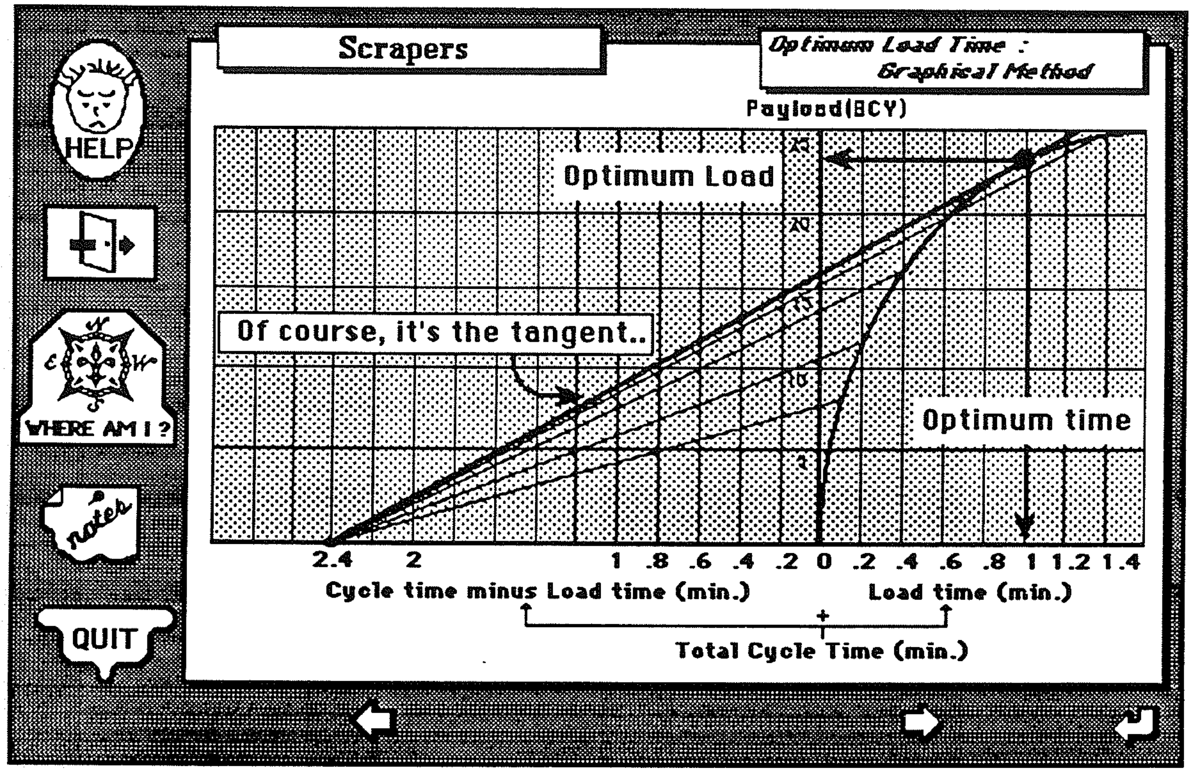

Figure 10. Example of an active graphic

Video still frames. Video still frames mainly emphasize different components of the various types of scrapers. The are pedagogically equivalent to slides shown in class or pictures in a textbook. For example, ConEq includes pictures of each of the major types of scraper, plus close-ups of components such as the apron, cutting blade, bail, etc.

Video motion picture segments. Segments of continuous video are the main tool for presenting real site operations. They enable the user to watch as well as to analyze the productivity of certain operations. In the scraper module, these segments illustrate different loading and dumping techniques as well as show the various types of scrapers in action.

Sound. Computer-generated speech optionally can be turned on to guide the user through the module, and comment on the user's actions while analyzing the video segments. A program called MacinTalk generates speech customized to each user (e.g., it can address a student by name). Also, some of the video segments include accompanying sound tracks with engine noises and narrative explanations.

Examples of Student Interaction with ConEq

Although space does not permit even a partial reproduction of a full example showing the system in use (just a few minutes of interaction typically covers several computer screens and hundreds of frames of video), we will reproduce and briefly explain a few typical screens that might be encountered in a study session dealing with scrapers.

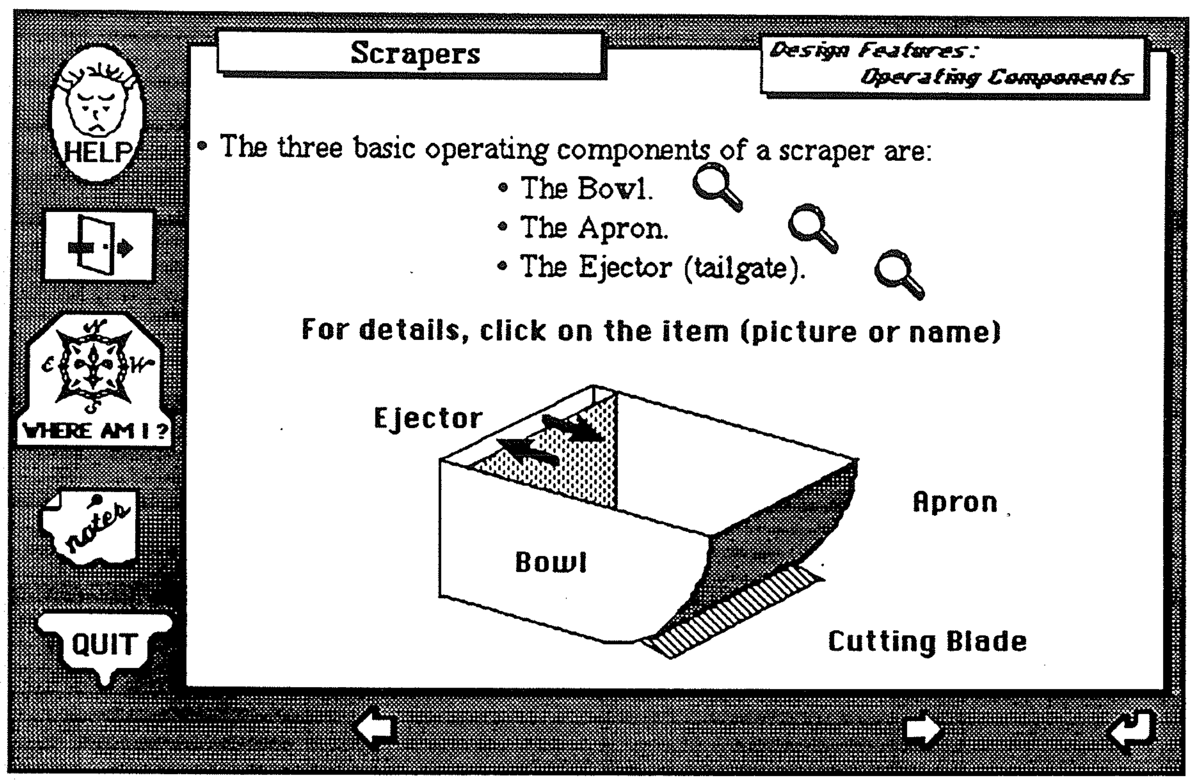

Figure 11. Navigating by clicking a portion of a picture

Browsing and study. At one level, sometimes called *browsing,* the system simply presents information. The student navigates from card to card, reads or sees what each has to say, looks at animated graphics and video segments, and explores the effects of active graphics. For example, early in the session the student might use this method to learn about design characteristics of scrapers. Figure 6 presented a screen that listed the main types of scrapers, and from there the student could branch to several different modes of information presentation, as explained earlier for the magnifying glass icon, the ellipses icon, the eye icon, and the camera icon.

In addition to clicking icons or text segments on a screen, clicking on portions of a graphic image can also bring up more information on that subject. For example, clicking on the ejector part of the scraper bowl in Figure 11 will cause the program to branch to more detailed screens on that topic, including a video sequence showing the ejector being used to dump the load from a scraper.

Interactive exercises. Four types of exercises in the Scrapers module provide the user with means to evaluate his or her state of knowledge at any time. The system responds by collecting the answers, changing the active graphics, or commenting using text or sound.

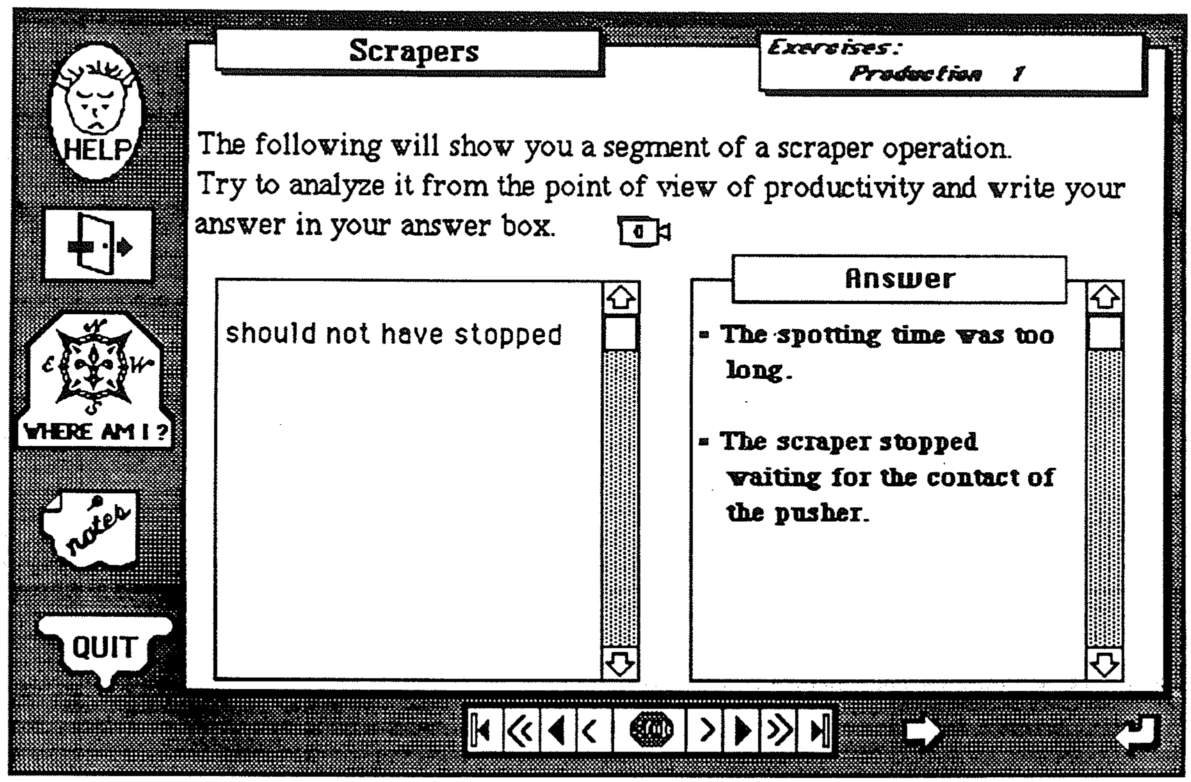

Figure 12. A typical question card (user has already seen the right answer)

Multiple choice exercises can respond to a user's wrong answer by displaying a brief narrative of the right answer, or by taking the user immediately to review the card(s) that was applicable to the question. In the latter case, the user is then returned directly to the question to try again, or to continue on to the next one. *General Problems* exercises test the user's ability to apply the analytical and computational skills that he or she gained in the module to calculate the right answer to a given problem. These sections (much too detailed to show here) take the student sequentially through analytical problems, much like a professor would do at a chalkboard, asking students to compute the next steps on their own before showing the work on the "chalkboard." *Video Analysis* exercises test the user's skill in analyzing a site operation and collect his or her answers in a special file for the instructor's evaluation later. *Training* exercises help the user to make instantaneous site decisions. They combine the use of video segments and active graphics, which affect the production of the whole operation. While the first two types of exercises are fairly conventional, video analysis and training need further explanation.

A typical screen requesting a narrative response to a video analysis question is shown in Figure 12. In this case, the student first clicks on the camera icon to critically examine a segment of video showing a scraper and pusher getting ready to load. The student should then state what was wrong in this case by typing in the field on the left. He or she could compare this answer to the system's by clicking on "Answer" above the field on the right, producing a response such as that shown. If the student's input is to be graded like homework or a test, the system can be set so that the student must type in a response before looking at the system's answer, and not be allowed to go back and change his or her own answer after that.

In a typical training exercise, the student simultaneously watches a scraper loading on the TV screen or window while the load-growth curve is plotted, as shown in Figure 13. After clicking *Start,* the student can click the *Stop,* advance (up arrow) or back-up (down arrow) buttons at any time, and immediately see the current productivity data as a new line in the table on the left. The growth of the graph is synchronized to the amount of material loaded in the scraper in the video, so this exercise gives the student some feel for what the operator must do to recognize and stop at the "optimum" load.

Creating a record of student input. As mentioned, the system automatically collects a student's responses to questions. The student has the freedom to edit his or her answer—or even go back and review pertinent cards—up until he or she clicks to see the right answer. The student's responses along with the corresponding questions are collected under the student's name and identification code in a separate file for the instructor's evaluation at a later time.

Evaluation of Teaching Effectiveness

The system was used as the sole teaching tool for material pertaining to scrapers in CE 145, Spring Quarter, 1989 and again in 1990. We collected student feedback by watching them interact with the system, by administering questionnaires seeking their critique of design features in the system, by discussing their experiences with the system, and by listening to their suggestions for further improvements. The students agreed on the power, effectiveness and ease of use of ConEq. A good performance on related questions on homeworks and on the CE 145 midterm and final exams also confirmed the strength of the system as a teaching tool.

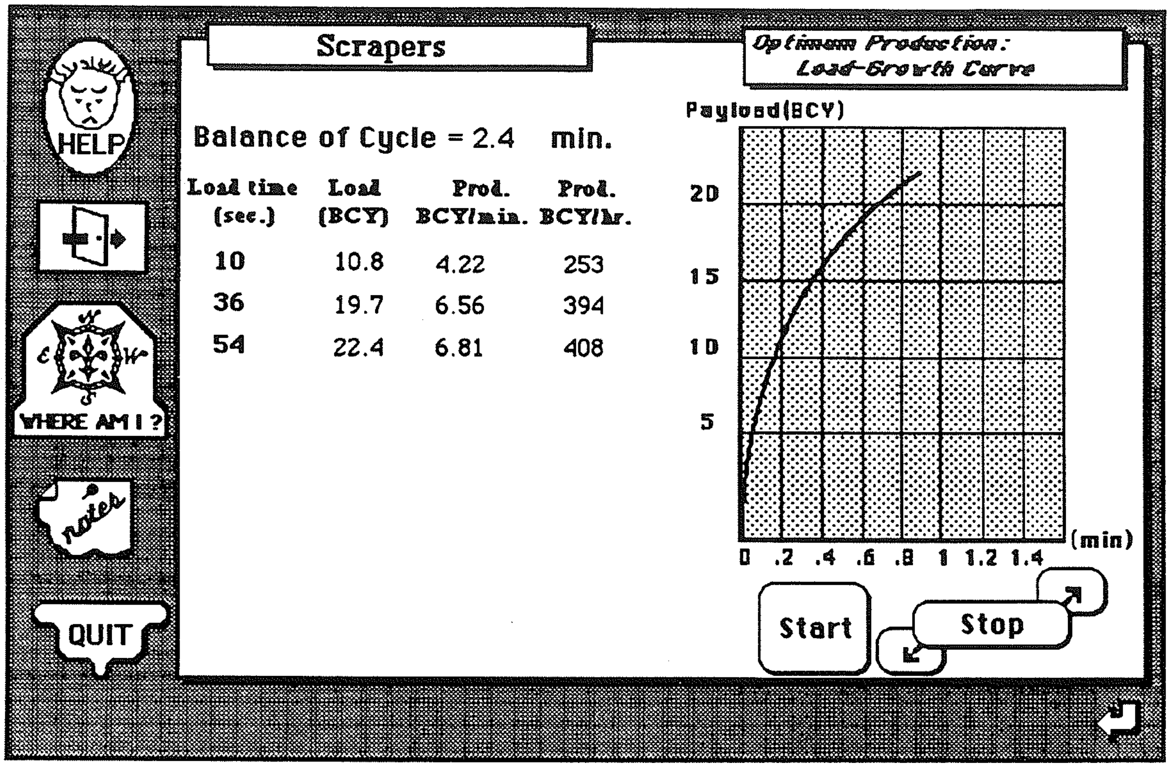

Figure 13. Load-growth curve exercise

This prototype convinced us that interactive multimedia educational systems of this type can flexibly be tailored to the needs of individual students to stimulate their interest and attention. These techniques, already successful in other fields (medicine, language, theater, history), have a strong potential to improve teaching productivity and effectiveness in civil engineering and construction. The teacher may indeed become more of a tutor for several things going on at once. In general, we envision few limitations of these techniques for the development of educational applications.

Cooperative Development

This type of system lends itself well to cooperative development and sharing of courseware by educators working at several colleges and universities and also by instructors in industry. The advantages include not only the sharing of the workload, but more importantly the ability to tap the knowledge of experts in various areas, and then pool this expertise in a set of multimedia course modules. Specialized courses, excellent teaching and other strengths of one instructor or institution can be made available to many others in courseware reproduced and distributed for wider use. These techniques also provide excellent potential to disseminate more effective training in industry and government. Additional applications could include preserving for future use detailed construction methods that solved previous field problems faced by a corporation.

The main potential obstacles to such development are 1) the expertise to work with the development software, and 2) standards for the microcomputer/videodisc workstations. Working with the system that has been described, we found it relatively easy for a person with some knowledge of computer programming to soon become productive in courseware development. The Scrapers module took only about three months of part-time graduate student work as our first step on the learning curve. This included collecting the relevant video material, preparing the artwork, etc., with only a small fraction of the time being devoted to actual programming in a relatively simple scripting language. Similar expertise is found in most engineering departments.

The issue of standards is a little more difficult at present. While many colleges and universities have Macintosh computers, others use IBM PCs and compatibles, as does much of industry. This implies at least two parallel development efforts, although the availability of translation software (mentioned in the next section) somewhat eases the burden. The tougher problem at present is the need for specialized videodisc players, although time should take care of that, too.

Development System and Methodology

The hardware employed to develop the system described here is an Apple Macintosh II microcomputer and a Panasonic Model TQ-2027F optical disc player. The system's programming uses the Macintosh HyperCard® software (HyperCard 1987, Goodman 1987). Special drivers, written for use through HyperCard, control the optical disc player to provide quick access to still and continuous video images pertinent to the subject. Our primary sources of video material were marketing, safety and training tapes provided by Caterpillar, Inc. (Caterpillar videotapes 1,2 and 3). Frames and segments from these tapes were extracted, edited and consolidated onto an 8-inch optical videodisc using a recording version of the aforementioned Panasonic player that is available in a central facility at Stanford.

The chosen methodology can create an interactive, mentally stimulating environment in which the user must think and respond on-line. HyperCard provides flexible access to text, graphics, and video images adapted to the interests and abilities of different users. Moreover, the flexibility and ease of use of HyperCard provide advantages in design and implementation. Using HyperCard, the system is workable at any stage of implementation, yet is flexible to edit, update, or change.

Recently, software has become available to support similar applications on IBM PC and compatible microcomputers using Microsoft's MS-DOS operating system. At least one package offers the ability to partially translate HyperCard applications to run in its own PC environment (Spinnaker PLUS® 1990). We have experimented somewhat with this software and confirmed that it does offer similar capabilities. The main disadvantage is that it is extra-cost third-party software, whereas HyperCard is part of the standard package of software delivered with every Macintosh.

The main limitation at present for replicating our system is the expensive and specialized optical disc player. We chose this model rather than the more common ones used for consumer-type videodiscs because it offers the facility incrementally to add video material quickly and more cheaply using optical write-once-read-many (WORM) technology. To make a disc for one of the conventional players, one must collect all of the needed video information together onto a high-quality videotape, and send it to a third-party firm to produce the disc at a much higher cost. In the near future, it is expected that a microcomputer standard for such video media will evolve, and that inexpensive devices will become available on most computers. Thus we view our present disc hardware as an interim technology that suits our development purposes, but do not see it as the vehicle for wider dissemination. When standard low-cost microcomputer videodisc technology does become widely accepted, we expect to be able readily to copy over our video material with few changes needed to the supporting ConEq software.

Conclusion

We are still a long way from mesmerizing students with our construction material to the extent that is accomplished with videogame machines. Compared to developers of videogames, we are relative novices in the application of multimedia technology. Indeed, educators could benefit from some professional help from the experts. However, we have seen enough to know that the potential is there. Student reaction to our software developed thus far has been positive, and testing indicates that ConEq does at least as good a teaching job as a well rated instructor. We have not even begun to tap the benefits of flexible curriculum design and customizing courses to individual needs and interests that the technology allows, but the demand for this is there.

The supporting development technology is certainly at a level where individual professors and their assistants can create their own courseware at modest expense. Where professional help would be most valuable is not in the actual programming, but in the design and presentation of material in a truly stimulating and well organized manner.

Having proven that the technology works, it is time to disseminate it more widely in engineering education, and to stimulate reciprocal and cooperative efforts to develop and refine quality material that covers a much broader range of the curriculum. No one professor is the best at all subjects, and by pooling resources, drawing upon the best of what is available, and disseminating the results, the overall standard of education could be enhanced. Doing this systematically would certainly benefit from coordination and programmatic funding, and standards would be helpful once the technology settles down a bit, but useful progress can still be made on an *ad hoc* basis even without such central resources. The main need now is to establish communications links among educators and developers, and broaden the understanding of the potential for what this technology offers.

Acknowledgements

For this development work (El-Bibany and Paulson 1990), we were supported by the Center for Integrated Facility Engineering (CIFE) at Stanford, which is operated jointly by the Departments of Civil Engineering and Computer Science and has corporate members from the design, construction and computer industries and representatives from owners and government agencies. The equipment videotapes were generously provided by Caterpillar, Inc. The videodisc drivers were provided by Charles Kerns at the Laboratory for Authoring Multimedia Projects (LAMP), which is run by Stanford's Academic Information Resources Department.

References

[Caterpillar 1989] *Caterpillar Performance Handbook* , edition 19, Caterpillar, Inc., 1989.

[Caterpillar videotape 1] *Different Types of Scrapers*, videotape, Caterpillar, Inc.

[Caterpillar videotape 2] *The Edge in Mining*, videotape, Caterpillar, Inc.

[Caterpillar videotape 3] *Making the Most with a Scraper*, videotape, Caterpillar, Inc.

[El-Bibany and Paulson 1990] El-Bibany, H., Paulson, B.C., "CONEQ: A Multi-Media System for Teaching Large-Scale Field Construction Equipment and Methods", Working Paper number 9, Center for Integrated Facility Engineering, May, 1990.

[Goodman 1987] Goodman, D., *The Complete HyperCard Handbook*, Bantam Books Inc., September, 1987.

[HyperCard 1987] *HyperCard® User's Guide*, Apple Computer Co., Cupertino, California, 1987.

[Nunnally 1977] Nunnally, S.W., *Managing Construction Equipment*, Prentice-Hall, Inc., 1977.

[Peurifoy and Ledbetter 1985] Peurifoy, R.L., Ledbetter, W.B., *Construction Planning, Equipment and Methods*, Fourth Edition, McGraw-Hill Book Company, 1985.

[Spinnaker PLUS 1990] Spinnaker PLUS® Manuals, Spinnaker Software Corporation.