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A SYSTEMS APPROACH TO COMPUTER-BASED TRAINING

Gaylen W. Drapé
ENSCO, Inc.
445 Pineda Court
Melbourne, FL 32940

ABSTRACT

This paper describes the hardware and software systems approach used in the Automated Recertification Training System (ARTS), a Phase II Small Business Innovation Research (SBIR) project for NASA Kennedy Space Center (KSC). The goal of this project is to optimize recertification training of technicians who process the Space Shuttle before launch by providing computer-based training courseware. The objectives of ARTS are to implement more effective CBT applications identified through a needs assessment process and to provide an enhanced courseware production system. The system's capabilities are demonstrated by using five different pilot applications to convert existing classroom courses into interactive courseware. When the system is fully implemented at NASA/KSC, trainee job performance will improve and the cost of courseware development will be lower. Commercialization of the technology developed as part of this SBIR project is planned for Phase III. Anticipated spin-off products include custom courseware for technical skills training and courseware production software for use by corporate training organizations of aerospace and other industrial companies.

INTRODUCTION

Global competition and rapid changes in technology have increased the demand for employee education and job training. There are three major reasons for this increase in demand [1], the first being that displaced workers need to be retrained. It is estimated that most workers will change jobs five or six times during their lives. Due to the dynamic nature of the U.S. economy, 1.5 million workers are permanently displaced each year and require assistance to reenter the workforce. By the year 2000, it is estimated that 5 to 15 million manufacturing jobs will require different skills than for today's jobs, while an equal number of service jobs will become obsolete.

Second, the work being performed at most companies is becoming increasingly complex. The use of computers and more sophisticated business processes require many employees to relearn how to perform their jobs. Furthermore, competition demands that there be constant change in the products and services that companies offer. This causes a ripple effect throughout the company in bringing these new products and services to customers.

Changes in the organizational structure of companies also increase the demand for job training. One result of the difficult economic climate is that many companies are downsizing, increasing the need for cross training of workers. One of the principles of Total Quality Management (TQM) is the expansion of employee empowerment, with teams of employees performing a function or process with little or no direction from traditional management. Companies that are turning to TQM principles are finding that employees are unqualified for this empowerment without a large investment in training.

The United States' educational system fails to prepare many employees for the challenges of the modern workplace. The poor performance of U.S. high school graduates relative to their foreign counterparts on standardized tests is well publicized. Without supplementary training, the level of education of available American workers frequently fails to meet the requirements of employers. A recent study shows that one-fifth of displaced workers lack a high school education and that 20 to 40 percent of these workers are considered functionally illiterate.

Due to changes in the economy and increases in skill level requirements for the workforce, many companies have expanded their employee training programs. Typical employee development programs at many large companies now include remedial training in reading, writing, and basic mathematics. Also, increased quality and safety requirements have caused companies to institute formal job or skill certification programs. However, the increased necessity of workforce training is costly in terms of time away from the job, travel costs to and from training sites, and expenses associated with classroom facilities, instructors' salaries, and administration.

Patients who have experienced discomfort on traditional computer keyboards have found relief when using "THE VERTICAL". Further research with keyboard users showed individuals, and especially industry, will not accept a product which forces them to relearn the keyboard or takes extensive amounts of time to regain normal speed and accuracy. Based on the comments of hundreds of people who have interfaced with "THE VERTICAL" prototype, an average touch typist will regain speed and accuracy within hours.

COMPETITION

"THE VERTICAL" will compete with other companies which develop and market ergonomic computer keyboards, some of which are of greater size and may have greater financial resources. Ergonomic-Interface Keyboard System Inc.'s major competitors are the manufacturers of new "ergonomic" keyboard styles. However, those new keyboard styles which allow the user to pronate their hands and wrists during keystroking, maintain a "flat" keyboard similar to the major manufacturers, thereby incurring the same potential problems to the user. Others stray from the standard QWERTY key configuration and eliminate traditional typing formats altogether. They insist the user learn a new operational language in order to operate the board. Since, over the years, other unconventional keyboards such as the Dvorak System have been introduced yet have not been accepted by industry due to the need of retraining the user, it is felt by industry experts any keyboard which strays from the QWERTY format will not be accepted by the masses. One of the competitors states the optimal, ergonomic keyboard operates with the user's hands in a vertically oriented position, yet their keyboard does not offer the user that possibility without eliminating the visual connection from the user to the board. Existing major computer keyboard manufacturers and major computer companies which manufacture their own keyboards are not considered competition due to existing lawsuits against them stemming from their ill-designed "flat" or "conventional" keyboards.

Competition exists between the Company and some ergonomic experts who ignore the physical problems which the computer keyboard has been accused of creating. Their opinion is with proper body positioning and the correct use of properly designed ergonomic furniture, the problems of RMI and CTD could be eliminated. This is not the opinion of most medically and/or orthopaedically trained physicians. It does not address the damage keystroking plays on the user's body while the hands and wrists are pronated and arms are projected forward from the shoulders. Body position and furniture type alone cannot correct RMI and CTD problems. However, the Company does agree proper body positioning and the correct use of properly designed ergonomic furniture should be utilized while using "THE VERTICAL" so as to enhance the value of the keyboard's design.

Some experimentation has begun with hand written data entry, but this has limited application at best (for limited use by physically disabled operators, etc.). The error factor is also a serious problem with hand written data entry.

FUTURE PRODUCTS

The long term goals of The Company are towards the modification of other data input devices to obtain benefits similar to those of "THE VERTICAL". Adaption of the basic design to meet specialized keyboard styles for governmental and research usage is expected to be an easy transition. Another logical extension of this design, which is now being worked on by The Company, is a vertically oriented Stenograph device.

Means must be found to make employee training more cost effective. Computer-based training (CBT) has been available for many years as either an alternative or a supplement to classroom training. Government-sponsored research and companies' experience have shown CBT has the following potential benefits over conventional instructor-led training.

- Training can be delivered and administered at lower cost.

This is possible because a computer can be placed at or near the work site at a time that is convenient to the learner. Traditional classroom instruction settings and instructors are unable to provide the level of flexibility in location and time that a computer is able to. CBT can be delivered close to the work site and can be scheduled at a time that is more convenient to the learner. Delivery of training on the computer also makes the course content more consistent and maintainable.

- Training can be accomplished in less time.

CBT allows individualization of lessons, whereby students access only the information that they need to learn. The modern "point-and-click" user interface commonly used in CBT gives the learner increased control of the lesson and allows the training to be self-paced. Thus, faster learners are able to complete lessons in less time.

- Computer-based training improves learning when the training program is effectively developed.

By building the capability for increased interaction into the lesson, immediate feedback and remediation is available to students. It is now possible to integrate audio and video into CBT presentations that appeal to multiple senses and various learning styles of students. Therefore, learners are more highly motivated to complete the training program.

- Training achievement can be measured and tracked more easily.

CBT enables tests and assessments to be embedded into the course, making recordkeeping easier. Student performance data can be stored for later analysis to improve lessons.

Despite the potential benefits of CBT, the technology has not yet fulfilled its promise to make significant improvements in employee education and job training. Most applications of CBT are used in the United States military for combat training of personnel. Many of the training programs created for the military used specialized high-end applications developed for proprietary computer hardware. CBT did not become widely used in industry because it was too expensive to develop and the need for sophisticated training was not justified. Within the past few years, however, advances in personal computer hardware and software have made CBT more capable and affordable. The remaining challenge lies in demonstrating that CBT can be a cost-effective method of employee training in commercial industry.

PROJECT BACKGROUND

In January 1991, ENSCO, Inc. in Melbourne, Florida was awarded a Small Business Innovation Research (SBIR) contract to provide the Kennedy Space Center (KSC) with enhancements to its computer-based training. The focus of our project was to develop courseware for recertification training of technicians who perform pre-launch processing of the Space Shuttle. Processing of the shuttle vehicles requires that shuttle technicians be certified in approximately 500 technical skills. These skills include the operation of specialized test equipment, as well as performance of various types of mechanical and electrical repairs to the shuttle vehicle and its major systems. KSC's technical training program requires that most technicians be recertified annually by attending a classroom refresher course and taking an examination. With each technician holding approximately seven certifications, this process takes more than 6000 worker hours per month away from work schedule. The purpose of ENSCO's SBIR project is to apply CBT technology to existing recertification training courses, the result being the more effective delivery of training in less time than with conventional classroom training.

Investigations of the target population and the types of work performed produced a number of factors that support the benefits of CBT over instructor-led training for skill recertification. First, shuttle technicians have varying training needs that tend to favor self-paced learning. Training requirements differ for electrical technicians, mechanical technicians, and quality control inspectors. Depending on the individual technician's job, a particular knowledge or skill may be performed at a varying time interval. This variance can result in a heavy "forgetting curve" of the skill for some technicians but in little or none for others. Evidence also indicates that, due to differences in their ages and reading comprehension levels, technicians use diverse learning techniques.

Another major factor favoring CBT is the dynamic nature of the shuttle processing work schedule, which depends upon the particular operations and maintenance tasks performed on the shuttle vehicle after each mission. Coordinating technicians' training requirements with the changing work schedule presents challenges to the existing certification program. There are a number of instances in which a job cannot be performed as scheduled because a technician cannot attend the recertification class. There are also occasions when too many "no shows" in the classroom cause the cancellation of a scheduled training course.

In January 1991, ENSCO began the research and development (R&D) effort on the process to convert existing recertification courses to CBT. This project required a strong working relationship between ENSCO and the Lockheed Space Operations Company (LSOC), which was the prime contractor responsible for shuttle processing and implementation of the technician training program. ENSCO also enlisted the services of the University of Central Florida to consult on training systems analysis and design.

During Phase I of the SBIR contract, an early prototype application was delivered on a stand-alone PC. This prototype demonstrated the feasibility of CBT for recertification of typical shuttle processing tasks and showed that CBT could be accepted by technicians. However, Phase I research also showed the development process for sophisticated CBT was complex, particularly where multimedia computer technology was required. It was also determined that CBT would eventually need to be delivered by way of a network to achieve the greatest usage cost savings. Therefore, improvements in both the development and distribution systems were needed for CBT to be produced and distributed on a larger scale.

ENSCO's goal during Phase II of the project was to apply recent commercially available technology to the CBT process, which would result in a more efficient and cost-effective medium for recertification training. Our technical approach consisted of two major objectives:

1. To provide a process for selecting good applications for CBT and determining the content of the CBT programs.

2. To make the system for developing and maintaining CBT programs less costly and easier to use.

Each of these objectives was addressed to overcome weaknesses in the current CBT system. In the following sections, these objectives are discussed in more detail.

NEEDS ASSESSMENT PROCESS

The first objective was satisfied with the needs assessment process. Needs assessment is a term that has many meanings in training and human performance literature. [2] The definition that seems most applicable to this project is *the analysis of the training situation for the purpose of defining the requirements of a CBT development project.* The needs assessment is conducted prior to the design of the CBT program. Its purposes are to identify the training goals and objectives and to select the appropriate media with which to present the content. A thorough needs assessment ensures that the instructional objectives are congruent to the performance job or task. A needs assessment also provides the basis with which to make rational decisions about how to apply CBT in the training program.

The needs assessment process applied by ENSCO can be described in two stages, as shown in Figure 1. The first stage is task analysis, which determines the training objectives – what the trainee needs to know or needs to do to perform a task. Prior to analysis, data are collected from the existing lesson plans, from interviews with subject matter experts and, if necessary, from observations of the task being performed. These data are then analyzed and a list of the knowledge and skills needed to perform the task is compiled. It is also important to identify prerequisite skills and knowledge during the analysis to avoid expending effort on developing unnecessary training content.

The second stage of the needs assessment process, media selection, determines the most effective way to provide the training. The inputs to the media selection process are the target audience characteristics, the training objectives, and the environment in which the training program will be deployed. The actual selection process ranges from a simple checklist verifying that CBT is a viable alternative to a comprehensive model for determining the best media to fit a particular set of training requirements and constraints. Possible choices include a hypertext document, an interactive multimedia courseware program, a system simulation, or an intelligent tutoring system.

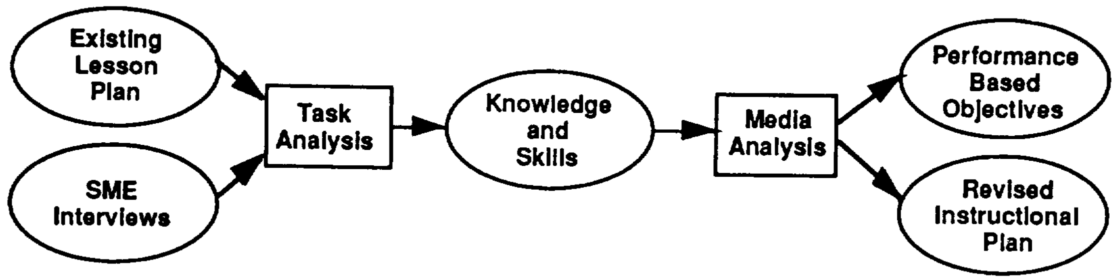

Figure 1. Needs Assessment Process.

The outcomes of the needs assessment are a data base of training objectives and a revised plan of instruction. The objectives data base usually has a hierarchical structure in which broad job performance goals, also known as terminal objectives, are divided into specific learning (or enabling) objectives. Building the objective hierarchy is a crucial step in CBT development, as it becomes the foundation for the courseware design. Each objective should be linked to storyboards for laying out the instructional content and to the testing items for verifying that the student has met each objective. The second outcome of the needs assessment is a plan of instruction. This plan should include the level of the media chosen to fit the target audience, the training environment, and the total cost estimated for the project.

There are major benefits to having a needs assessment. First, the assessment generates information with which to justify that the selection of CBT will result in improved trainee job performance. Second, there is a reduction in course design and development time as a result of the assessment's identification of specific performance-based objectives for the CBT program. This results in the training content being more relevant, increasing the probability that students will accept and use the program.

CBT PRODUCTION SYSTEM

One of the reasons that CBT is not widely used is that good CBT courseware has high development costs. Producing effective CBT is a complex undertaking that requires a team whose members have both creative and technical skills. These skills include:

- script writing
- graphic arts
- audiovisual production
- subject matter expertise
- instructional design
- computer programming
- systems engineering
- performance measurement and assessment

Building interactive CBT programs that are instructionally sound and interesting to the student requires a structured, yet flexible, design approach. CBT should be designed and built according to guidelines for screen design, instructional strategies, and testing methods. These guidelines have been established by educational psychologists and human factors engineers. For this project, the detailed requirements and standards used in the CBT lessons were established during the needs assessment phase of the project.

A CBT production system was created and was used by development team members to build courseware according to established standards and guidelines. The hardware and software components of the production system were configured using commercially available computer technology. Three major technical concerns influenced the creation of the production system:

1. The hardware and software needed to be compatible with those used at KSC.

2. The most sophisticated courseware applications to be produced would require interactive videodisc and digital audio capability.

3. Some members of the CBT development team who would be using the system lacked extensive programming expertise.

Since most of the CBT at KSC uses the IBM PS/2 platform, we selected compatible CBT production system hardware. This hardware configuration consists of the following components, as shown in Figure 2:

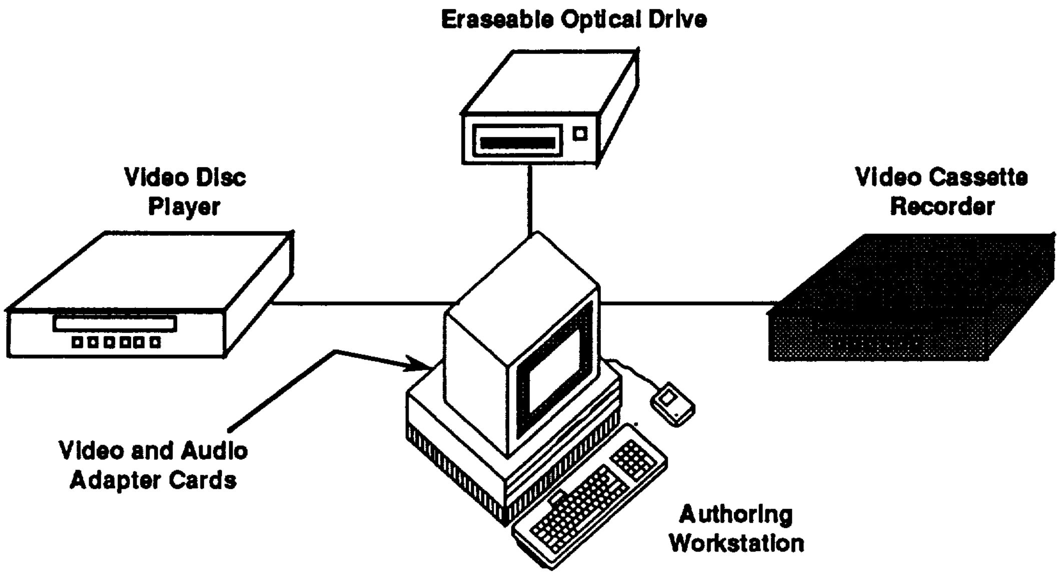

Figure 2. CBT Production System Hardware Configuration.

Most of the effort in creating the production system was expended in building the software environment. The system needed the capability for allowing the production of sophisticated CBT programs, while providing ease of use for members of the development team who were not experienced programmers. The software approach taken by ENSCO used a commercial-off-the-shelf authoring package as a foundation or shell and to integrate customized CBT production tools within the shell. The software configuration can be described as a pyramid, which is illustrated in Figure 3. Using this system, courseware programs could be written using the capabilities of the authoring package, the operating system, and the other system software that allowed operation of peripheral devices such as the audio card and videodisc player. The authoring package, Asymetrix® ToolBook®, was chosen because of its compatibility with other CBT development efforts at KSC. This version of ToolBook® runs under Microsoft Windows™ and comes with multimedia libraries that contain software drivers for audio and video hardware devices.

The major features of the production system environment are listed below.

- Password-protected access for student, developer, and system administrator

- Hierarchical structure of scripting programs for ease of maintenance

- Standard logic flow for different modes of instruction and reference, ensuring all training objectives are achieved by the student

- Templates for screen construction that assume common user navigation and media controls
- High level language for creation of time-sequenced presentation of media on the screen

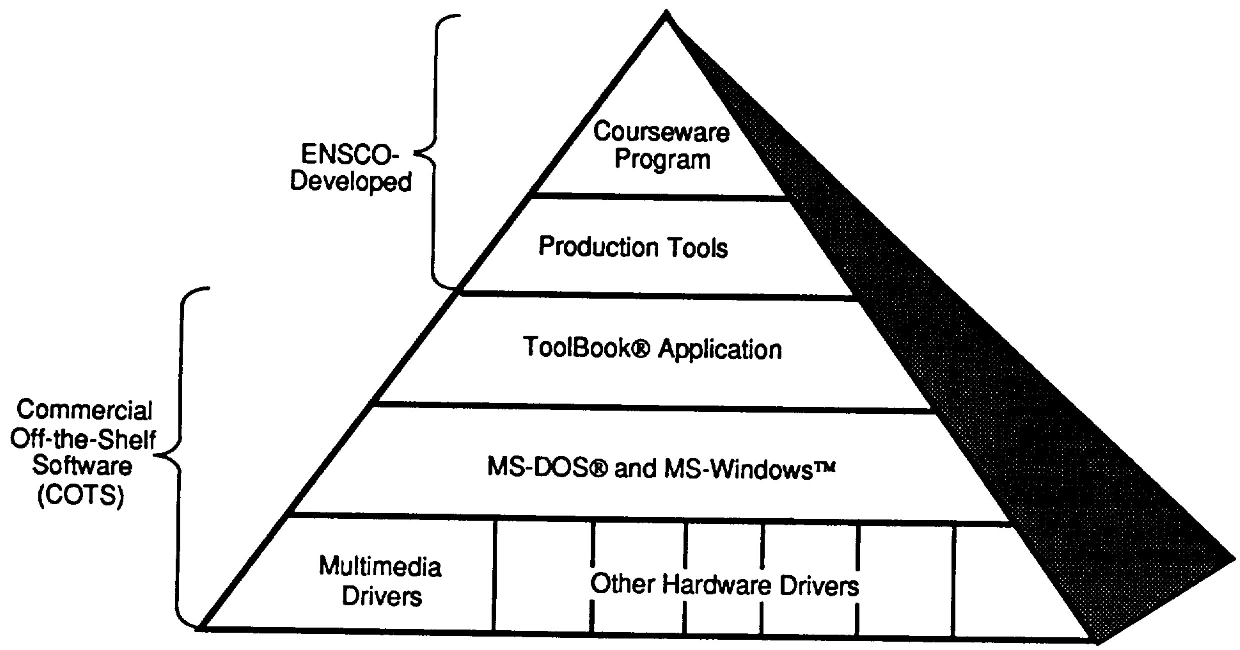

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Figure 3. CBT Production Software Environment.

- Test engine for construction of test questions with question-answer randomizing capabilities and feedback
- Development tools for showing and hiding media objects and for debugging the programs

The benefits of the production environment include quality and functionality consistent with instructional system design principles, reduction in programming expertise required, and provision of a facility for program reuse and maintenance.

PROJECT RESULTS

Since Phase II of the project began in May of 1992, the system and technical approaches have been evaluated with actual KSC training courses that were converted to CBT applications. These pilot applications were selected primarily to illustrate how CBT could be used for training over a wide range of technical subject matter. The applications were also evaluated using the needs assessment process to determine their appropriateness for CBT. Examples of the types of training applications for which CBT programs were developed included:

- Operation of a helium mass spectrometer for leak testing shuttle components
- Operation of a computer-controlled laser tool for measuring steps and gaps between Orbiter tiles
- Safety precautions to be taken to counteract the hazards involved with high-pressure systems

In the remaining five months of Phase II, we plan to deploy and evaluate the pilot courses in various training environments with diverse target populations. We designed pilot courses to use different media at different levels of sophistication – from a hypermedia reference manual to interactive multimedia courses for recertification with built-in proficiency testing. The delivery methods by which the pilot CBT applications will be evaluated include stand-alone PCs, on-line local area networks, and concurrent training applications. CBT applications will be evaluated for use as a means of automated recertification, as a classroom training aid, and as a reference tool for the workplace.

Initial data gathered from pilot studies show that the new approach favorably influences the training process. Using self-paced CBT, we expect that students will be able to cover course content in 25 to 50 percent of the time it would take them to cover the same material in a traditional classroom setting. We also expect a significant reduction in CBT development time because less programming will be required. Finally, we have CBT design standards to follow, making courseware more consistent and maintainable.

COMMERCIAL APPLICATIONS

The plan for Phase III of this SBIR project is to commercialize the technology developed as part of this project. As explained earlier, the market for CBT training in government and industry is expected to expand because of changes in the economy and demographic trends in the workforce. Insufficient numbers of instructors available to meet increasing training demands, as well as rapid growth in computer technology, will increase CBT's market potential by its capability to disseminate information and increase interactivity with students at a steadily decreasing cost.

Our primary targets for marketing CBT technology are training departments of small and mid-size companies that require custom training and skills certification courses. A secondary marketing opportunity is to produce software to augment major CBT authoring systems.

ENSCO's systems approach is to harness technology to make CBT a more efficient and effective training method. The primary ways to make this happen are to select appropriate CBT applications and to specify lesson content accurately through the needs assessment process. Another means by which to increase the value of CBT to commercial industry is to reduce development and maintenance costs through enhancements of the CBT production system.

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[2] The Design, Development, and Evaluation of Instructional Software, Hannafin, M., and Peck, K., Macmillan, New York, NY, 1989.