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AUTHOR	Fletcher, J. Dexter
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ABSTRACT

This study was performed in response to the 1989 Department of Defense Appropriations Bill, which directed the Department of Defense to conduct a study on the use of interactive videodisk technology in education and training as it pertains to effectiveness, cost effectiveness, time on task, retention, and overall applicability to current and future Department of Defense (DoD) training and education requirements. A quantitative meta analysis was performed of 31 evaluation studies concerned with interactive video instruction. Across the evaluation studies reviewed, interactive video instruction was found to be more effective than conventional approaches to instruction. The effectiveness was enhanced further by the utilization of more interactive features and directed rather than freeplay simulations. Use of interactive video can increase training efficiency by increasing opportunities for practice and requiring students to participate more actively in instruction. Three studies indicated that retention using interactive video instruction is at least equal to that found using other instructional approaches. Interactive video is a promising and cost-effective medium that will have a significant impact on military systems. An executive summary of a study of the effectiveness of interactive videodisk in army communications training and a list of organizations contacted are appended. (58 references and 2 tables) (GL)

REPORT TO CONGRESS ON THE POTENTIAL OF INTERACTIVE VIDEODISC TECHNOLOGY FOR DEFENSE TRAINING AND EDUCATION

J. Dexter Fletcher

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IDA
Institute for Defense Analyses
1801 N. Beauregard Street, Alexandria, Virginia 22311

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SUMMARY

Background

The challenges facing military trainers are substantial and growing. Trainers have sought new approaches in instructional technology to enable them to meet these challenges. Interactive videodisc instruction requires students to participate actively in the training environment, it provides students access to high quality simulation of devices that could not otherwise be made available to them, and it distributes both the content and interactions of high quality training to widely dispersed sites. As a consequence, interactive videodisc instruction has been prominent among the new approaches pursued by the Department of Defense, and Defense research and development laboratories have been leaders in developing new instructional approaches based on interactive videodisc technology.

Purpose

This study was performed in response to the 1989 Department of Defense Appropriations Bill which directed the Department of Defense to conduct a study on the use of interactive videodisc technology in education and training as it pertains to effectiveness, cost-effectiveness, time on task, retention, and overall applicability to current and future DoD training and education requirements.

Approach

A quantitative, analytic review was performed of evaluation studies concerned with interactive videodisc instruction. It is the first "meta-analytic" review undertaken for videodisc instruction. Thirty-one studies were identified as appropriate for inclusion. Of these, 15 concerned military training, 3 concerned industrial training, and 13 concerned applications in higher education.

Findings

Overall effect size obtained from this anal; was .51, which suggests that through the introduction of interactive videodisc instruction 50th percentile students might be expected to perform at what is currently the 70th percentile. Different results were obtained for different instructional settings. The average effect size obtained for military training was .35, suggesting a rise for 50th percentile students to the 64th percentile. The average effect size obtained for industrial training was .30 suggesting a rise for 50th percentile students to the 62nd percentile. The average effect size obtained for higher education was .70, also suggesting a rise for 50th percentile students to the 76th percentile.

Interactive videodisc instruction has been demonstrated to be the preferred cost-effective alternative in several specific applications. Cost ratios for interactive videodisc applications over alternative approaches ranged from .02 to 4.49, suggesting wide variability.

One study was found that discussed time on task as a result of introducing interactive videodisc instruction -- time on task in this study increased by 45 percent.

Superior performance by interactive videodisc groups was sustained over retention periods ranging from one to ten weeks. However, performance of the interactive videodisc groups grew closer to that of groups using other instructional approaches over these retention intervals.

Conclusions

The following were the conclusions of this study:

Effectiveness:

1. Across the evaluation studies reviewed, interactive videodisc instruction was more effective than conventional approaches to instruction.

2. The more the interactive features of interactive videodisc technology are used, the more effective the resulting instruction.

3. More positive results were obtained for interactive videodisc applications in higher education settings than in military and industrial training. Training -- as opposed to educational -- management practices most probably accounted for these differences by training directly to specific tasks and limiting achievement to thresholds of performance and knowledge required by the tasks.

4. Directed, tutorial approaches are more effective than freeplay simulations in interactive videodisc instruction.

5. Interactive videodisc instruction is equally effective for imparting knowledge and improving task performance skills.

Cost-Effectiveness:

Interactive videodisc instruction is a viable cost-effective alternative in training and should routinely be considered as an option in the design of military training programs.

Time on Task:

Interactive videodisc instruction can increase the efficiency with which training time is used by increasing opportunities for practice and requiring students to participate more actively in instruction. One study was found that addressed this issue, and its results supported this possibility.

Retention:

Given the nature of interactive videodisc instruction, it is reasonable to expect it to produce equal or longer retention of skills and knowledge. Three studies were found that addressed this issue, and their results suggest that retention under interactive videodisc instruction is at least equal to that found under other instructional approaches.

Final Comment

The results of this study indicate that interactive videodisc instruction is a promising approach, that it can have a substantial impact on the return from resources allocated to military training and education, and that if vigorously pursued it will have a significant impact on people-related aspects of military systems and consequently on our security. While there are research questions yet to be answered concerning this technology, it is clear that it has matured sufficiently to be employed in many areas of military training and education.

I. INTRODUCTION

Purpose

This study was performed in response to the 1989 Department of Defense Appropriations Bill which directed the Department of Defense to conduct a study on the use of interactive videodisc technology in training and education as it pertains to effectiveness, cost-effectiveness, time on task, retention, and overall applicability to current and future DoD training and education requirements.

The Office of the Secretary of Defense (OSD) has an empirical investigation already in progress concerning the effectiveness of interactive videodisc instruction. This investigation addresses issues raised by the above direction from Congress, and its Executive Summary is included with this report as Appendix A. On the other hand, the Department of Defense has been a leader in the development of interactive videodisc technology and has completed many evaluative investigations of its applications in instruction. For this reason, a quantitatively-oriented, analytic review -- a "meta-analysis" -- of what has been learned about the effectiveness and cost-effectiveness of interactive videodisc applications in military training, industrial training, and higher education was undertaken and completed in response to the Congressional direction. Although several such reviews have been completed for other technology-based instructional approaches such as computer based instruction, this review is the first of its kind undertaken for interactive videodisc instruction.

Background

The challenges faced by military trainers are substantial now and can be expected to increase in the future. There are at least five reasons for these challenges. First, the supply of people available for military service is decreasing. The number of people reaching age 18 each year has been dropping substantially. This decrease is not expected to level off until the mid-1990s.

Second, the number of military systems is increasing. In keeping with modernization and battlefield demands for technology, the number of materiel systems fielded by the the U.S. military has increased substantially since World War II. If no technological changes were made in the complexity of military systems, their quantity and variety would by themselves increase the challenges to military training.

Third, the technological complexity of military systems is increasing. Whether or not the complexity of military systems translates into increased job complexity is arguable. Nonetheless, the demand for people prepared to hold jobs classified as technical or highly technical has increased across the Services.

Fourth, costs to conduct training have risen in both absolute and relative terms. Fuel and ammunition have been major contributors to military training costs. Fuel costs will never return to pre-1970 levels, and ammunition costs continue to rise along with the sophistication of our new systems.

Fifth, Reserve component training poses particularly difficult requirements. The role of the Reserve Forces in the Total Force clearly shows that the Reserves are no longer in reserve. They will be among the first forces committed to battle in any future war. However, the Reserve components have a limited amount of time to train, units are widely dispersed throughout the country, units are not fully equipped, and only a small full-time force of qualified supervisors and trainers exists in Reserve units.

It is not surprising to find military trainers seeking new approaches to meet these challenges. It is also not surprising to find them turning to our most powerful new technologies for these approaches. Interactive videodisc technology has been prominent among these. Like computer based instruction, interactive videodisc instruction requires students to participate actively in the training environment, it allows students access to high quality simulation of devices that could not otherwise be made available to them, and it distributes both the content and interactions of high quality training to widely dispersed sites. As a consequence, the Department of Defense has been a leader in developing new instructional approaches based on interactive videodisc technology.

This approach involves coupling videodiscs and videodisc players with computers. Generally, the videodisc serves as a storage medium for much of the curriculum data base and the computer controls how and in what order the curriculum material is presented to students. In this sense, interactive videodisc instruction is a form of computer based instruction, but the substantial power and numerous capabilities added by videodisc technology serve to place it in a category by itself.

The videodisc itself uses a reflective, metalized plastic disc on which information is coded as tiny pits (about 0.5 microns in diameter) which are pressed into a transparent substrate with a reflective coating. During play of the disc, the pits modulate a laser signal that is decoded into audio and video signals. About 15 companies possess manufacturing methods and processes to master and replicate such discs from a master videotape submitted by a curriculum developer. The first copy of a disc may cost \$2,000-\$3,000, but additional copies cost less than \$20 depending on quantity. The Department of Defense has specified the LaserVision format for production, and its approaches to interactive videodisc instruction use videodiscs as very large read-only storage for some or all of the curriculum data base.

Videodiscs are available in several sizes -- the most common are 8 inches and 12 inches in diameter. The 12 inch interactive videodisc can store 30 minutes of full-color video, or 54,000 video frames, on each disc side along with two tracks of audio. With audio compression, 150 hours of audio can be stored on each disc side. Videodiscs can store digital as well as analog data. Depending on size and format they can store 200-3000 megabytes (assuming 8-bit bytes) of information. An interactive videodisc system is an audiovisual instructional system using a "personal" microcomputer, videodisc player, monitor, and special interfaces for displaying graphics and controlling the player. Such a system will generally cost \$4,500-\$8,000. The videodisc player and its interface typically adds about \$2,500 to a personal computer system.

New optical technologies such as CD-ROM (compact disc-read only memory), CD-I (compact disc-interactive), and computer generated imagery will compete for the market currently held by interactive videodisc systems based on 12 inch discs. However, the instructional capabilities -- the functionalities -- of interactive videodisc systems are the essence of a study such as this one. Whatever the hardware media eventually chosen to deliver them, the functionalities currently made available by interactive videodisc technology well deserve assessment for their current and potential impact on instruction.

Much of the development of instructional functionalities now found in both computer based instruction and interactive videodisc technology has been supported by the Department of Defense (Power On!, 1988). Fletcher and Rockway (1986) review the history of these contributions and identify five new functionalities developed by the Department of Defense for interactive videodisc instruction. These five are the following:

1. Surrogate travel. This capability simulates a path of travel selected by the user over an area stored on videodisc. Areas chosen for initial demonstration of this capability include a town (Aspen, Colorado), a harbor, a nuclear power plant, and an art gallery. Using this capability, the user may choose the path, control the speed of advance, and direct the angle of view while "traveling" through an area using simple controls -- usually a joystick. When the user comes to a choice point such as an intersection, he/she can turn right, turn left, proceed ahead, or go back under joystick control. The videodisc frames the user sees originate as filmed views of what one would actually see in the area -- possibly including what one would see at different times of day or at different seasons of the year.

2. Interactive movies. One problem with training that requires demonstrations of skilled performance is that essential components of the demonstrations are invisible to viewers. Interactive movies are intended to solve this problem by allowing the user interactive control over many aspects of viewing such as direction (front, side, above, below), speed (fast, slow, still-frame, reverse), detail (panning and zooming), abstraction (photographs, labeled line-drawing animations), plot (different actions at different choice points), and simultaneous action (gauge readings, actions outside of the current angle of view).

3. Microtravel. This capability combines surrogate travel with interactive movies and allows travel through places where people cannot go. One demonstration of this capability involved travel through a jeep engine while it was running.

4. Spatial data management. Electronic libraries in the form of spatial data management systems allow users to "fly-over" spatially organized data using joystick controls. Data elements are associated with familiar terrain (e.g. a university campus) so that anyone familiar with the terrain can locate data of interest -- information on chemistry would be found by "flying" to the chemistry department, information on tuba concertos might be found by "flying" to the tuba section of the university symphony orchestra found in the music department, and so on.

5. Low-cost portable simulators. One of the first military skill training videodiscs was an Army tank gunnery trainer. This interactive videodisc simulation uses motion video segments stored on videodisc to provide a tactical environment and targets. The student selects ammunition, aims, and fires using computer generated imagery overlaid onto the video display to receive round trajectory and burst on target feedback.

Of the approximately 100,000 videodisc systems currently in non-consumer use in the United States, about half are used for training (Miller, 1987). The effectiveness of these applications is of significant and natural interest both inside and outside the Department of Defense. The effectiveness and cost effectiveness of these applications are the primary topics of the study reported here.

II. APPROACH

This study benefited from other reviews of interactive videodisc instruction. These reviews include those by Bosco (1986), DeBloois, Maki, and Hall (1984), DeBloois (1988), and an annotated bibliography compiled by Sarli, Nau, Martin, Kanitz, and Williams (1988). On the basis of these reviews, it was evident that the state of our knowledge would support a quantitatively oriented, analytic review of interactive videodisc effectiveness. This review forms the core of the study documented here.

Technical Approach

The methodology used for analytic reviews has changed somewhat in the last 10 years. The "box score" approach which earlier characterized the methodology has been replaced by "meta-analysis." In the box-score approach, studies in which an experimental group exposed to the treatment under review are collected, the proportion of studies in which the experimental group means exceed control group means by some statistically significant extent are calculated, and the treatment is reported as favorable or not depending on whether this proportion is large or small. Hedges and Olkin (1980) have shown that the box score approach has very low power for the treatment effect sizes and sample sizes characteristic of social science research. They also showed that the power of the procedure decreases as the number of studies included in the review increases.

Glass (1976) proposed an alternative approach. Since he was performing an analysis of analyses, he described his alternative as "meta-analytic." It differs from the box-score approach in three ways: (1) studies relevant to the issue at hand are collected using clearly defined procedures that can be replicated; (2) a quantitative measure, "effect size," is used to tabulate the outcomes of all the collected studies including those with results that are not statistically significant; (3) statistical procedures are used to synthesize the quantitative measures and describe the findings of the analysis. Glass's approach appears to be especially appropriate for synthesizing the results of instructional research, and it has been widely used for this purpose since its introduction.

Meta-analysis is a new technique and some matters concerning its use remain unsettled. The issues receiving the most attention at present appear to concern the "file-drawer problem" and calculation of effect size. Additionally, the use of meta-analysis to perform research syntheses that include costs, i.e., syntheses involving cost-effectiveness, remains unaddressed and undetermined.

The file-drawer problem stems from the reluctance of professional journal editors to include studies whose results fail to reach statistical significance -- these studies, therefore, remain in file-drawers. The question, then, is how much effect would these inaccessible studies have on the results of our meta-analyses? After some analysis, the answer according to Rosenthal (1984) and others seems to be not much. In this study, it will be noted that steps were taken, perhaps inadvertently, to alleviate the file-drawer problem.

Effect size is usually defined as the difference between the means of two groups divided by the standard deviation of the control group. Glass, McGaw, and Smith (1981) suggest that choice of the denominator is critical and that choices other than the control group standard deviation are defensible. However, they endorse the standard choice -- using the control group standard deviation -- and that is the approach used here.

A quantitatively oriented synthesis of costs and meta-analytic measures of effect has yet to be devised. An approach using statistically adjusted comparisons based on analysis of covariance is currently being developed by the Institute for Defense Analyses, but it is as yet too experimental for use in studies such as this one. Moreover, the amount of systematically collected data now available on the costs of interactive videodisc development and use is presently too small to support such an analysis.

<u>Data Collection</u>

This study was intended to pursue a meta-analytic approach as closely as possible. Defense Technical Information Center, Educational Resources Information Center, and Psychological Abstracts data bases were searched using all combinations of the following:

[Computer <or> videodisc]
<and>
[Assisted <or> Aided <or> Mediated <or> Managed <or> Based <or> <Empty>]
<and>
[Education <or> Learning <or> Training]

Additionally, we used the following terms by themselves:

Interactive Videodisc
Interactive Video
Interactive Courseware.

This search process turned up more than 2400 candidate studies. Most of these studies, however, concerned computer based instruction alone and not interactive videodisc instruction. It was not without value, however, and about 10 of the 23 studies listed in Table 1 were identified through this search. On the other hand, there were studies that were known to exist but did not appear in this search. Some of these studies are unpublished and not catalogued anywhere. Others are published but evidently not catalogued using any of the above keywords. Still others exist only as laboratory reports. Whatever the case, we were forced to decide whether or not to include studies that did not turn up in our formal, meta-analytic search. We chose to include them, and we decided to search for more.

To increase the basis of evaluation studies, we contacted cognizant individuals in the training commands of all three Services (US Army Training and Doctrine Command, US Navy Chief of Education and Training, and US Air Force Air Training Command), in the personnel research and development commands of all three Services (US Army Research Institute, US Navy Personnel Research and Development Center, and US Air Force Human Resources Laboratory -- among others), and in specific Service schools where we knew interactive videodisc materials had been used.

We also contacted industrial training organizations to see if they had evaluation data and if they were willing to release it to us. We pursued this by publishing a notice in the Videodisc Monitor, by calling every developer listed in the IBM's March 1988 InfoWindow Courseware Catalog, and by calling every developer listed in the 1988-1989 Videodisc Compendium for Education and Training. With these actions we hoped to unearth "fugitive" documents that had reported studies performed for business but had not been published. Few such documents emerged. We were impressed by the willingness of people to root through their personal files for us and dig out references that were already in the published literature. Some of these references had not been identified by our search of the data bases, and we were glad to know about them.

Finally, we called a number of researchers in universities. As usual we encountered helpful, facilitating people who were willing to dig through their personal files and send us whatever they felt would be relevant.

In nearly every case, our telephone calls led us to additional individuals. We are grateful to all who helped. We contacted over 250 organizations, and they are listed in Appendix B.

The criteria we applied to the studies that turned up were systematic and likely to better satisfy meta-analytic purists. All the usual criteria for care and control in the conduct of evaluation research studies were applied. These are the criteria that are likely to be discussed in any good university course on the design and conduct of experiments in the social and behavioral sciences. Additionally we applied the following three criteria:

1. We required studies that involved a comparison of an interactive videodisc approach with some other approach to instruction. It is possible, if not desirable, to evaluate an instructional approach without a comparison. For instance tracing a "trajectory" of student progress through a course as described and applied by Suppes, Fletcher, and Zanotti (1976) is more powerful than the experimental group, control group comparisons we sought here. However, we needed comparisons to calculate effect size, and we excluded studies without them.

2. We required studies that reported sufficient data to permit calculation of effect size. Generally, we needed means and standard deviations for all treatment groups. In the absence of these data we were often able to estimate effect size from other information provided -- especially information obtained from significance tests. Glass et al. (1981) describe a number of ways to calculate effect size when means and standard deviations are not provided directly. We used these when we could, and we included all the studies that we could.

3. We required studies that involved students who resemble the military personnel who are our primary concern. We did not include studies involving children or handicapped individuals. We found no candidate studies involving non-handicapped children, but we did not search as assiduously for these as we did for others. We did encounter 2-3 studies involving handicapped students that were otherwise acceptable, but we did not include them in this study.

Tabulation of Findings

Our search identified the 31 studies referenced in Table 1. The table is organized so that military training studies are listed first, industrial training studies are listed next, and higher education studies are listed last. Within these groups, the studies are listed chronologically. We did not exclude secondary school studies, which would have made up a fourth instructional setting category; none were identified in our search. Two studies were performed at the US Air Force Academy (Crotty, 1984; Verano, 1987). Although these studies used military subjects, the setting seemed more characteristic of higher education than military training, and they are included with the higher education studies.

The main distinction in the instructional approach column is among those applications that used the videodisc as a tutorial, programmed textbook -- the intrinsic programming approach advocated by Crowder (1959) -- those that used the videodisc to permit free exploration of simulated situations or equipment, and those that used both by combining tutorials with simulations.

Disc levels were assigned in keeping with the definitions developed by the Joint Service Ad Hoc Committee for Interactive Courseware Data Item Descriptions. This committee based its definitions on those developed by the University of Nebraska Videodisc Design and Production Group. These definitions in turn were derived from common developer usage. They are the following:

Level 0 -- A videodisc system intended for linear play without interruption.

Level I -- A videodisc system with still/freeze frame, picture stop, frame and chapter search, dual channel audio, but no programmable memory. All functions are intended to be initiated by manual inputs from the videodisc player's keypad. Picture stop and chapter stop are read from the videodisc.

Level II -- A videodisc system with on-board, programmable memory. The videodisc player's memory is programmed by "digital dumps" from audio channel two of the videodisc or by manual entry from the videodisc player's keypad. Inputs are made from the keypad or from a device that emulates the keypad.

Level III --- A videodisc system in which the videodisc player is interfaced to an external computer. The videodisc player acts as a computer peripheral with its functions under the computer's control.

Level IV -- A videodisc system in which the videodisc player is interfaced to an external computer and the videodisc is used to store digital data intended to be read and used by the computer. The videodisc functions both as an optical storage device for digital information and as the source of analog picture and sound.

All five definitions are listed here for the record. Only two levels (II and III) were found among the studies listed in Table 1. The term 'interactive videodisc' in contrast with 'videodisc' alone typically implies the presence of a computer, and it is used to refer to a Level III or Level IV videodisc.

Outside of what could be determined by descriptions of the instructional approach and the level of videodisc used -- and of course what can be determined from the evaluation results, no direct review of interactive videodisc content was attempted in this study. We did not attempt to review such features as the quality of graphics, clarity of instructional text, and verisimilitude of the simulations stored on the videodiscs used in the evaluation studies we found.

The 'N' column lists the number of subjects in the experimental (Exp) and the control (Ctrl) groups, and the Comparison column tells what the experimental and control treatments were. Generally the experimental group involved interactive videodisc (IVD) presentations, and the control group did not. In some cases, different interactive videodisc presentations are compared with each other, and in one case a comparison of computer based instruction (CBI) with the control treatment was included in the study and is reported in the table. A common treatment in maintenance and operator training involves the use of interactive videodisc to simulate actual equipment (AE).

The basic distinction in the Outcome column appears to be between knowledge and skill, that is to say between those studies that assess students' knowledge of the presented subject matter and those studies that assess students' skill in performing some criterion task(s).

Effect size was calculated as the difference in the group means divided by the control group standard deviation. In some cases, effect size was estimated using procedures suggested by Glass et al. (1981). Also in some cases, the means and standard deviations were not reported in the referenced study, but they were obtained through personal communication with the study author(s).

Some studies involved simultaneous comparison of more than two treatment groups and began with an analysis of variance (ANOVA) before proceeding to compare the treatment groups in a pairwise manner. The statistical significance of the analysis of variance comparison is reported in the table. All effect sizes reported were calculated from pairs of treatments. Generally, effect size was calculated so that it was positive if the difference favored the videodisc treatment and negative if it favored the control treatment. More specifically, and to cover cases such as those in which different videodisc treatments were compared with each other, effect size was always calculated so that it was positive if it favored the instructional treatment judged to be the most interactive of the pair. The treatment judged to be most interactive was always the first of the two treatments listed in the corresponding Comparison column.

The abbreviation 'ns' is used in the Effect Size column to indicate that the observed difference in treatments was not statistically significant. Otherwise, the significance level reported in the study is listed. The abbreviation 'na' is used in the Effect Size and the Cost Ratio column to signify that the data of interest were not available and not reported.

The signs of values reported in the Percent Improvement column were determined in a manner similar to that used for the Effect Size column. It was calculated so that it is positive when the difference favored the most interactive treatment, i.e., the treatment listed first in the corresponding Comparison column.

Cost ratios are reported as the ratio of videodisc treatment costs over the control treatment costs, or, again, the most interactive treatment costs over the other treatment costs. The closer the proportion is to zero, the more favorable it is to the more interactive (generally the videodisc) treatment. Generally, we did not find costs to be reported in these studies, although many authors acknowledged cost and cost-effectiveness to be significant issues. Cost models usually cover costs in four categories: research and development, initial investment, operating and support, and recovery and salvage. All cost ratios found and reported in Table 1 are based on initial investment (II), operating and support (OS) costs, or both.

III. FINDINGS

Effectiveness

Indications of the effectiveness of interactive videodisc applications in training and education can be obtained by combining the effect sizes reported in Table 1. Different combinations will yield different results, but it will be noted that the overall picture is favorable.

Not all the effect sizes reported in Table 1 are appropriate for this study. We need to select more carefully the effect sizes we actually use to calculate an overall average. In making this selection we eliminated three sorts of findings from the calculation:

1. Some of the effect sizes reported in Table 1 are included for completeness and involve comparisons against control treatments in which no relevant instruction was provided. These comparisons were included in the original studies to determine if interactive videodiscs teach anything. As might be expected, the effect sizes reported for these comparisons are large and favorable. Of the seven effect sizes reported for these comparisons, four are in excess of 1.00. However, these comparisons do not involve two different approaches to providing instruction, and they were eliminated from further calculations.

2. Other effect sizes reported in Table 1, and also included for completeness, do not involve interactive videodisc applications at all. Three of the post-ANOVA pairwise comparisons reported by Levenson et al. and one reported by Gibbons, et al. did not involve interactive videodiscs, and their effect sizes were eliminated from further calculations.

3. Finally, studies involving Level II videodiscs were also eliminated from the calculation. This is in keeping with the usual definition of interactive videodiscs.

This selection does not exclude effect sizes based on comparisons of different levels -- or "intensities" -- of interactive videodisc treatments such as those reported by Cicchinelli et al. (1984) and by Verano (1987). In these comparisons, the treatment that most used the interactive capabilities of the technology -- the most intensive treatment -- was considered as the experimental approach and the other as the control.

As a result of these procedures, we included 95 effect sizes from Table 1. Of these, 78 are positive and indicate positive results favoring the most interactive treatment of the treatment group pairs considered. The effect sizes range from -1.14 to 2.49. Their mean is .51, and their median value is .46. This average is 20-90 percent larger than effect sizes reported in meta-analyses of computer based instruction (cf., Niemiec and Walberg, 1987).

Although effect size appears to be an excellent metric for aggregating the results of many different studies, its implications for the practical world of instruction are not immediately evident. Roughly, a mean effect size of .51 from a sample as large as 95 suggests that, through the use of interactive videodisc technology, a trainer can expect to increase the performance of his/her graduates by about one-half a standard deviation above their present level of achievement. This is, roughly, to say that his/her average graduate, the graduate at the 50th percentile, could be performing at the level of his graduates now at the 70th percentile through the use of interactive videodisc technology.

Table 1 was intended to invite exploration of the results. We calculated the averages for military, industrial, and higher education settings. The average effect size for military applications, based on 44 observations, was .35 -- suggesting a rise of 50th percentile students to the 64th percentile. There were seven observations for industrial settings. Their average effect size was .30 -- suggesting a rise from the 50th to the 62nd percentile. The average effect size for instructional applications in higher education was based on 44 observations. It was found to be .70 -- suggesting a rise from the 50th percentile to the 76th percentile.

Another exploration concerned the instructional approach and the type of instructional outcome assessed. We categorized the studies into three groups based on their instructional approach. These groups keyed on treatments in which the instructional approach was directive and tutorial, those in which the instructional approach was based on freely explored simulations, and those that combined both tutorial and simulation approaches. We also contrasted studies in which the instructional outcome assessed was course knowledge with those in which the instructional outcome assessed was skill or performance. The results of this exploration are shown in Table 2, which also shows the average effect sizes for all tutorial approaches, all simulation approaches, all combined approaches, all knowledge outcomes, and all performance outcomes.

The results shown in Table 2 indicate that directive, tutorial approaches yield greater instructional results than simulation approaches. Of course, even if there were no differences in instructional effect between interactive videodisc simulations and use of actual equipment for instruction, the considerable cost avoidances to be realized from using videodisc simulations rather than actual equipment -- as well as the substantial increase in opportunities for laboratory-type practice -- would continue to argue strongly for the use of interactive videodisc applications in instruction.

Secondly, the results shown in Table 2 suggest an advantage for instructional outcomes based on knowledge compared to those based on skill performance. Here, confidence that the instructional outcome was correctly categorized should be high, but the difference between knowledge and performance outcomes could, for instance depend on the fact that about 53 percent of the performance results came from studies using the more successful tutorial approach either by itself or in combination with a simulation whereas 77 percent of the knowledge results came from studies using a tutorial approach. The difference between knowledge and performance outcomes may be explained by these differences.

Finally, it should be noted that even the smallest of these effects, undirected simulation to achieve performance outcomes, shows a positive average effect size of .05, which indicates that interactive videodisc instruction used in this way is at least as effective as more conventional alternatives. A little more should, and will, be said about the cost avoidances that can accrue from the substitution of videodisc simulated equipment for actual equipment in instruction. Even negative instructional outcomes requiring more time to reach criterion can prove to be cost-effective because of the relatively small cost of simulated equipment that reacts with the kinds of realism needed to achieve instructional criteria.

Student time savings of about 30 percent have been noted in analyses of computer based instruction starting with the widely noted Orlansky and String (1977) study and continuing on into the present. Only four studies in Table 1 report savings in the time students needed to reach criteria. The average effect size for time saved across these studies was .93. Interestingly, the average percent time saved across these four studies was 30 percent. Four studies do not provide a conclusive base, but this result suggests that the time savings for interactive videodisc instruction may be about the same as those for computer based instruction.

All the above results are promising, but they arise directly and in a straight-forward manner from available evaluation data on the effects of interactive videodisc applications in training and education. There are some final matters to note concerning the studies from which these results were drawn.

1. Most of the evaluations reported here were performed by developers who produced the interactive videodisc instruction being evaluated rather than by third parties. There are strengths and weaknesses in this approach. Developers are rarely indifferent to the success of their products and might, intentionally or unintentionally, bias the results of their evaluation. On the other hand, there are standards for the performance and documentation of evaluation studies. Observance of these standards can be assessed by others -- as they were in the search for evaluation studies performed here -- and the possibilities for bias in studies performed by well-intentioned developers should be minimal. Also, developers have a stake in an honest assessment of their products. Most of the developers and evaluators referenced here are scientists and technologists, not marketeers. At base, most evaluations are formative -- intended to suggest improvements and modification in the product and in the technology -- not summative or intended to prove its value in some conclusive manner. The better the information developers get, the better their products can become. Finally, developers are in the best position to evaluate their products. They understand better than anyone -- including the potential users of their products -- the probable strengths and limitations of what they have developed, and they are better prepared than anyone to devise an assessment of their product.

2. One real weakness of any evaluation of any new technology is that there is simply nothing else like it. Each new technology has its own strengths and weaknesses. If the evaluation is held to strict instructional controls based on one technology, the other, alternative technology will be at a disadvantage. This problem can be ameliorated somewhat, but not entirely, by focusing on the instructional outcomes and not on specifically what is done to accomplish these outcomes. Even in the best of situations, however, new approaches are unlikely to be used to best advantage. Among all the evaluations listed, we probably have not yet seen an optimal use of an instructional approach based on interactive videodisc technology.

3. A related problem arises in the comparison of a newly introduced instructional approach with an existing one. Very often, as Orlansky and String (1977) found, the instructional

materials prepared for the new approach are trimmed down and focused on the instructional outcomes, but the existing approach is, naturally enough, left as it is. In this way, some evaluations may be unintentionally biased in favor of the new approach.

In short, it is as easy to argue that the view of interactive videodisc applications seen here is overly optimistic as it is to argue that it is overly pessimistic. At present it seems best to rely on the data we have and to conclude that applications of interactive videodisc technology to the problems and processes of instruction offer genuine and demonstrable instructional gains over the approaches we use now.

Cost-Effectiveness

There are nine cost ratios reported in the studies listed in Table 1. Two of these are for initial investment costs (II), three for operating and support costs (OS), and four for initial investment costs and operating and support costs combined. These ratios are all calculated as the costs of interactive videodisc instruction over the costs of conventional instruction generally involving use of equipment. The ratios cited for initial investment costs are .27 and 4.49; those for operating and support costs are.03, .61, and .02; those for initial investment and operating and support costs combined are .94, .34, .44, and .05.

There are other studies to be mentioned in this regard. All these studies explicitly assume that the interactive videodisc training is at least as effective as the conventional training with which the cost comparisons are made. Doughty and Lent (1984) present two such comparisons, one of which involved actual costs. This comparison concerns a training facility for a large jet engine remanufacturing facility. Doughty and Lent estimated the total costs for procuring, installing, and maintaining interactive videodisc instruction for this facility over a ten year period to be $4,419,000. Three sources of major cost avoidances to be realized from installation of interactive videodisc instruction were identified. These are: engine failure avoidance, training cost avoidance, and staff savings. Doughty and Lent estimated the total ten year savings from these three sources alone to be $14,031,000, yielding a return on investment of 316 percent.

Many commentators have remarked on the advantages of computer based instruction and interactive videodisc instruction to deliver standardized, decentralized training to students -- rather than require that the students be delivered to the training. Walker (1985) presents an industrial training study in which the costs of delivering interactive videodisc instruction to remote sites is compared to the costs of centralized training. When the initial investment costs for developing and installing the interactive videodisc training are amortized over three years Walker showed that the costs per student are $1,568 for the centralized training and $553 for the interactive videodisc training -- a cost ratio of .35 for combined initial investment and operating and support costs.

After an extensive study on the feasibility, costs, and effectiveness of various methods for training smog check mechanics, Maher (1988) concluded that because of the elimination of instructors and reduced training time, videodisc instruction would provide the most cost effective approach of five that were considered for hands-on mechanic training and verification testing. Maher found that the costs for videodisc training would be $50.60 per student compared with baseline costs of $102.78 per student -- a cost ratio of .49 for combined initial investment and operating and support costs.

The substitution of interactive videodisc simulated equipment for the real thing -- the actual equipment -- will likely prove a significant source of cost avoidances. This issue was rarely addressed directly -- with real costs reported -- in the studies reviewed here. It should be noted that a similar question addressed by Fletcher and Orlansky (1989) for the substitution of computer based simulations for actual equipment in computer based instruction found cost ratios of simulated equipment to actual equipment that were as low as .01. Basically, these cost ratios can be as low as we want, depending on the actual equipment being simulated.

Another important area of cost avoidances is student time. If the 30 percent savings reported for students to reach threshold levels of performance obtains for interactive videodisc instruction as it does for computer based instruction -- and it seems reasonable to expect that it will --, then savings for some high student load courses may reach millions of dollars. A possibly more important source of savings suggested by Solomon (1986) would result from the reduced numbers of people the military would have to support in a job category by reducing the time needed to train people for it.

Clearly, the cost-effectiveness of interactive videodisc training can vary widely. It will depend on the objectives of the instruction and the resources required for other approaches, whether they are conventional or not. It appears to be an issue that cannot be determined in general, but must be determined on a case-by-case basis. On the other hand, there are at least some instances in which interactive videodisc instruction is the preferred cost-effective alternative, and as it becomes more commonly considered there may turn out to be many instances in which it is the preferred alternative.

Time on Task

Very little direct evidence exists to suggest that students using interactive videodiscs are or are not willing to spend more time in instruction or that the time they do spend in instruction is or is not more task centered than is the case for more conventional forms of instruction. A number of studies listed in Table 1 surveyed students' opinions of the interactive videodisc instruction they received. By and large these studies report that the students enjoyed the interactive videodisc instruction, they would recommend it to others, and they found it easy to use, all of which suggests that they might be willing to attend more directly to instruction presented using interactive videodiscs than they would to instruction presented using more conventional approaches. Student ratings of interactive videodisc instruction might well be attributed to a novelty effect and be expected to wear off. However, Baggett (1989, Personal Communication) reports that in her experiments, some of which are quite lengthy, it has not. Over time and extended use students continue to report high interest and enjoyment of interactive videodisc instruction.

Winkler and Polich (in press) investigated interactive videodisc instruction used to supplement actual equipment experience for military radio operators. They found that introduction of the interactive videodisc materials led to a 45 percent increase in the time students spent practicing radio installation. In effect, these students received increased practice without increasing the amount of time they spent in the training course. In other words, they increased the amount of time they spent on the learning tasks.

Retention

Given the involving, if not compelling, nature of much interactive videodisc instruction, it seems reasonable to expect it to be memorable -- skills and knowledge obtained under interactive videodisc instruction should be retained at least as long and perhaps longer than skills and knowledge obtained under other instructional approaches. Three of the studies in Table 1 -- Bunderson et al. (1984), Verano (1987), and Young and Tosti (1981) -- addressed retention. All were concerned with the retention of knowledge rather than skills. Effect size for the two measures reported by Bunderson et al. reduced from an average of .60 to .41 over the 1-week retention interval studied. Effect size for the three measures reported by Verano reduced from an average of 1.86 to 1.28 over the 4-week retention interval studied. Effect size for the single measure reported by Young and Tosti increased from -.39 to +.14 over a retention interval of 10 weeks.

In these three studies, the experimental groups and the control groups seem to have grown together over the retention interval. How quickly their differences decrease and whether or not all differences eventually disappear are questions that cannot now be answered using available data and that await further research.

Some recent research suggests that retention is very sensitive to the choice and sequence of instructional media. Baggett (1983) showed that performance on assembly tasks assessed after a 1-week retention interval was significantly improved for students who had hands-on practice first and viewed a film second rather than the other way around. More recent experimental work by Baggett (1988) has shown no advantage in retention obtained from hands-on practice presented at the same time as audiovisual instruction -- groups without practice performed as well as groups with practice under these conditions. She did show an advantage in both immediate and 1-week delayed performance for practice and audiovisual instruction that was presented sequentially and not simultaneously -- with the best results again being shown by groups who received the hands-on practice first followed by the audiovisual instruction and not the other way around. This result is notably in keeping with the informal observations of experienced military trainers that interactive videodisc instruction appears to achieve better results in advanced training than in beginning training applications.

IV. CONCLUSIONS

It should be emphasized that the results of this study and its conclusions concern instructional capabilities -- functionalities -- not hardware. To refer to these capabilities as interactive videodisc instruction is both convenient and intuitively reasonable, but it is the functionalities that count in instruction, not the hardware.

Hardware systems other than those that couple videodisc players to computers and that provide the same functionalities as interactive videodisc technology ought to achieve the same instructional effects as those observed here. At present there is no hardware technology that can competitively provide the same instructional functionalities as interactive videodisc systems. However, computer generated video, computer generated audio, and compact disc technology are all likely to encroach on the territory now held by interactive videodiscs. Two implications from this observation are: (1) the training and education communities need to understand and track new technological developments to assure that the functionalities they need are best obtained from the technologies they use; (2) the training and education communities need to understand as well as possible what functionalities they genuinely need to accomplish their missions -- we need to better understand the costs and effectiveness of specific functionalities.

The following conclusions are suggested by the results reported in this study:

Effectiveness

1. Interactive videodiscs can be used to teach. The nine comparisons, reported in Table 1, of interactive videodisc instruction with a "placebo" treatment in which nothing was taught resulted in an average effect size of 2.19 (a rise for the 50th percentile student to something in excess of the 98th percentile) for immediate tests of achievement and an average effect size of .87 (a rise for the 50th percentile student to the 80th percentile) for retention achievement tests given after some time interval.

2. Interactive videodisc instruction is relatively more effective than conventionally used approaches to instruction. Of the 95 comparisons included in the overall statistics reported for effect size in this study, 79 compared interactive videodisc instruction to conventional approaches. These 79 comparisons exclude those that compare interactive videodisc instruction with videotape or computer based instruction, or involve comparisons among

different videodisc approaches. The average effect size for these comparisons is .91 (a rise for the 50th percentile student to the 82nd percentile).

3. The more the interactive features of interactive videodisc technology are used, the more effective the resulting instruction. There are seven results reported in Table 1 for Level II videodiscs. The average effect size for these applications is -1.53. Six of these results came from the Holmgren et al. (1979) study in which Army Training Extension courses designed to be presented using audio tape and film slides were directly recorded on videodisc. The findings of this study suggest that tape-slide materials presented on a tape-slide medium will produce training results that are superior to those obtained when the same materials are presented using another medium. This finding should come as no surprise.

These findings further suggest that the less the unique capabilities of interactive videodiscs are used, the less the advantage gained from using the medium. This possibility is supported by comparison of the Wankel (1984) with the Stevens (1984) results. The same basic videodisc material ("Puzzle of the Tacoma Bridge Collapse") was used in both cases, and in both cases the same test of physics knowledge was used. When the videodisc was used with a Level II approach, the effect size was -.17; when the videodisc was used with a Level III approach the effect size was +.29. Verano (1987) used three levels of interactivity in his study (linear, segmented, and interactive). The higher the level of interactivity he used, the larger the resulting effect size became. Instructional evaluation generally requires a sizable body of research to achieve a conclusive result, but the combination of the Holmgren, Verano, Wankel, and Stevens results make a strong case for using the full capabilities of Level III videodisc media in instructional applications.

It should be noted that an extrapolation of this conclusion to Level IV videodisc materials is not warranted. The step from Level III to Level IV, under the definitions used by this study, does not mark any improvement in the way instructional materials are presented, only a change in the way they are stored. For that matter, the proprietary nature of all current approaches to encoding and decoding digital information on and off videodiscs coupled with the lack of additional instructional capabilities makes Level IV videodisc technology incompatible with current Defense initiatives to achieve courseware portability.

4. Interactive videodisc instruction appears to be more effective than computer based instruction without interactive video. The average effect size of .70 observed here for

interactive videodisc instruction used in colleges is considerably higher than both the average effect size of .26 found by Kulik and Kulik (1986) for computer based instruction in colleges and the average effect size of .42 found by Kulik, Kulik, and Shwalb (1986) for computer based instruction in adult education. The average effect size of .35 found here for interactive videodisc applications in military training is almost on the midpoint between the findings of the two Kulik et al. studies concerning computer based instruction. However, the effects of interactive videodisc instruction on achievement in military settings have most probably been damped by the administrative procedures of military trainers who generally seek thresholds of achievement, not maximized achievement.

The addition of videodisc capabilities ought to add some value to computer based instruction since it increases the cost of the hardware system by about $2,500 per system. Because of these cost-effectiveness trade-offs, and because of the different objectives of instructional programs, blanket recommendation for one or the other of these technologies appears ill-advised. Recommendations concerning the use of computer based instruction and interactive videodisc instruction in specific applications will have to be made on a case-by-case basis for the foreseeable future. However, it should be noted that strong evidence exists that each of these approaches can be more effective than conventional approaches to instruction.

5. Directed, tutorial approaches are more effective than freeplay simulations in interactive videodisc instruction. Evidently, guided discovery is worth more than simple discovery in instruction. Most of the tutorial approaches included in Table 1 included simulations of situations or equipment, and all the simulations must of necessity have provided feedback on the success of the student's actions. The main difference between the two approaches appears to be the extent to which the student was guided in his/her instructional interactions with the system. Guidance appears to pay off. The average effect size observed for tutorial approaches alone and tutorial approaches combined with simulation was .76 compared to an average effect size of .14 for approaches that more directly resemble straight simulations. This result is consistent with a body of literature that suggests that simulators and training devices are more effective when included in a training system than when they are simply used as stand-alone resources.

6. Interactive videodisc applications are relatively more effective in higher education settings than in military training. The average effect size observed in this study for higher education was .70, compared with an average effect size of .35 observed for military

training applications. This result is most probably due to the nature of military training in which the objectives are job driven and the practice is to aim for some threshold of achievement with minimized costs in contrast to instruction in education settings where costs are generally set at the beginning and the objective is to maximize achievement within these fixed costs. This possibility is supported b- the average effect size of .30 found for industrial training, which is managed in ways m closely resembling military training than higher education -- the attempt is generally to minimize costs to reach specific thresholds of achievement rather than to maximize achievement while holding costs fixed. Whatever the case, the average effect size of .35 observed for military training is substantial -- it suggests a rise for the 50th percentile student to the 64th percentile.

7. Interactive videodisc instruction is equally effective for both knowledge and skill outcomes. The average effect size observed for knowledge outcomes in this study was .59 (a rise for 50th percentile students to the 72nd percentile) compared with an average effect size of .38 (a rise for 50th percentile students to the 65th percentile) observed for performance outcomes. These differences are of practical significance, but they appear in this study to result primarily from the greater proportion of simulation approaches in those cases concerned with skill outcomes than from a difference in trying to obtain the different sorts of outcomes.

Cost-Effectiveness

Interactive videodisc instruction is a cost-effective alternative in training. The instances in which it can be demonstrated to be the preferred cost-effective alternative are sufficiently promising to conclude that it ought to be generally and routinely considered along with other instructional approaches now commonly considered during the design of instructional programs.

Time on Task

Interactive videodisc instruction may increase time on task. Intuitively, the low cost of interactive videodisc instruction relative to the costs of actual equipment should mean that students should be able to spend time actively engaged with equipment simulated by videodisc technology that they now spend passively watching demonstrations on actual equipment. Only one study reported an observation relative to this point. Winkler and Polich (in press) reported a 45 percent increase in the time spent practicing radio installation as a result of the introduction of interactive videodisc. This result seems best viewed as promising, but not conclusive. More work is needed which focuses directly on the topic.

Retention

Based on evidence presented here, there is no reason to believe that interactive videodisc instruction will have either a particularly beneficial or detrimental effect on knowledge or skill retention. Post-training experiences typically influence retention of knowledge and skills in a powerful manner. Defense experience with all new approaches to training has been that their promise and payoff resides primarily in improving the efficiency of instruction, not in assuring that what is learned will be longer retained. There is no evidence to suggest that interactive videodisc instruction will be any different in this regard.

V. FINAL COMMENT

It is clear from the results of this study that interactive videodisc instruction is a promising approach, that it can have a substantial impact on the value of resources we allocate to military training and education, and that if vigorously pursued it will have a significant impact on the people-related aspects of our military systems and consequently on our security. While there are research questions yet to be answered concerning this technology, it is clear that it has matured sufficiently to be widely employed in all areas of military training and education.

The Assistant Secretary of Defense for Force Management and Personnel has initiated a number of actions to insure that Defense training and education receive the full benefits of interactive videodisc technology and computer based instruction. These actions include the development of recommended practices for insuring that courseware will be portable across a variety of hardware and software systems other than those on which it was originally developed, the establishment of data collection, storage, and retrieval practices to insure that timely information on the applications of these technologies to Defense training and education is readily available, and the preparation of a Department of Defense Directive to establish policies and procedures for accomplishing these actions.

The Department of Defense pursues new approaches such as interactive videodisc instruction and computer based instruction because it must. Business as usual will not meet the challenges of fewer people, increased density of military systems, higher training costs, and Reserve Component training requirements. As we must modernize our forces by investing in new military systems, so we must also modernize our training technologies to supply the people we need to operate, maintain, and employ these systems at their intended levels performance. Without the people, these systems will provide us little in increased security.

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TABLES

Table 1. Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
Military Training	Armor Concepts	Slide/Tape Tutorial	II	16Exp 31Ctrl	IVD vrs Slide/Tape	Performance Test	-2.69 $p<.05$	-17%	na	Holmgren, Dyer, Hilligoss, and Heller (1979)
	Artillery Concepts		II	8Exp 33Ctrl			.85 ns	8%		
	Infantry Concepts		II	17Exp 31Ctrl			-2.70 $p<.05$	-18%		
	Armor Concepts		II	16Exp 31Ctrl	IVD with Review vrs Slide/Tape	Performance Test	-3.08 $p<.05$	-20%		
	Artillery Concepts		II	23Exp 33Ctrl			-.69 ns	-7%		
	Infantry Concepts		II	15Exp 31Ctrl			-2.20 $p<.05$	-15%		
Military Training	Electronics Maintenance	Practice on Simulated Equipment	III	27Exp 24Ctrl	IVD only vrs AE only	Paper Test of AE Knowledge	-.39[I,S,K] ns	-6%	na	Young and Tosti (1981)
						Test Using AE	-.31[I,S,P] ns	-1%		Also Ketner (1984)
						10-Week Retention of Knowledge	.14[I,S,K] ns	2%		
						Time to Criterion	-.15[I,S,P] ns	-2%		

Notes Concerning Effect Size:
I -- Included in Effect Size Overview Statistics; T -- Tutorial Approach only; S -- Simulation approach only;
C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
Military Training	Electronics Maintenance	Tutorial on Simulated Equipment	III	11Exp1 20Exp2 16Ctrl	CAI(Exp1) vrs CAI+IVD (Exp2) vrs Classroom(Ctrl)	Time to Complete Performance Test on AE	(ANOVA) na		na	Kimberlin (1982) Also in
					CAI vrs Classroom		.76 $p<.05$	32%		Gibbons, Cavagnol, and Lines (1982)
					CAI+IVD vrs Classroom		1.59[I,C,P] $p<.001$	68%		
					CAI+IVD vrs CAI		1.42[I,C,P] $p<.001$	53%		
Military Training	Electronics Maintenance	Tutorial on Simulated Equipment	III	72Exp1 72Exp2 72Ctrl	IVD/Hi+AE (Exp1) vrs IVD/Lo+AE (Exp2) vrs AE only(Ctrl)	Performance Test on AE	(ANOVA) $p<.001$		.94 (II&OS) (1)	Cicchinelli, Keller, and Harmon (1984)
					IVD/Hi+AE vrs AE only		.56[I,C,P] $p<.05$	14%	.84 (II&OS) (2)	Also in Cicchinelli (1984)
					IVD/Lo+AE vrs AE only		.46[I,C,P] ns	11%	.44 (II&OS) (3)	
					IVD/Hi+AE vrs IVD/Lo+AE		.12[I,C,P] ns	2%		

Notes Concerning Effect Size:
I -- Included in Effect Size Overview Statistics; T -- Tutorial Approach only; S -- Simulation approach only;
C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
				25Exp1 26Exp2 23Ctrl	IVD/Hi(Exp1) vrs IVD/Lo (Exp2) vrs AE only (Ctrl)	Performance Test on AE	(ANOVA) ns			
					IVD/Hi vrs AE only		.27[I,C,P] ns	8%		
					IVD/Lo vrs AE only		.16[I,C,P] ns	5%		
					IVD/Hi vrs IVD/Lo		.12[I,C,P] ns	3%		
					IVD/Hi(Exp1) vrs IVD/Lo (Exp2) vrs AE only (Ctrl)	Time to Complete the Performance Test	(ANOVA) ns			
					IVD/Hi vrs AE only		-.13[I,C,P] ns	-6%		
					IVD/Lo vrs AE only		-.23[I,C,P] ns	-10%		
					IVD/Hi vrs IVD/Lo		.09[I,C,P] ns	4%		
Military Training	Electronics Maintenance	Tutorial on Simulated Equipment	III	20Exp 20Ctrl	IVD and AE vrs. AE only	Time to Complete the Training	.90[I,C,P] $p<.001$	25%	na	Ketner (1984)

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C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
Military Training	Electronics Maintenance	Simulated Equipment	III	21Exp 22Ctrl	IVD vrs AE Practice	Course Knowledge Test (Paper)	.19 I,S,K ns	2%	.27 (II) .03 (OS)	Pieper, Richardson, Harmon, and Keller (1984)
						Procedures Performance Test	.33 I,S,P ns	4%		
						Completion Time for Above Test	-.27 I,S,P ns	-5%		
						Troubleshooting Performance Test	.93 I,S,P $p<.005$	19%		
						Completion Time for Above Test	-.08 I,S,P ns	-2%		
Military Training (Infantry Officers)	Military Operations on Urbanized Terrain (MOUT)	Simulated Reconnaissance Using Surrogate Travel	III	169Exp 156Ctrl	IVD vrs Conventional Training	Existing MOUT Performance Test	.15 I,S,P ns	2%	na	King and Reeves (1985)
				148Exp 150Ctrl		MOUT Simulation Test	.74 I,S,P $p<.05$	10%		
				148Exp 150Ctrl		Defense Deployment Test	.40 I,S,K $p<.05$	19%		

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C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent impr.	Cost Ratio	Reference
Military Training	Electronics Maintenance	Tutorial with Simulated Equipment	III	48Exp 51Ctrl	IVD+AE vrs AE Practice	Paper Test of Knowledge	.20[I,C,K] ns	1%	na	Wilkinson (1985)
						Performance Test on AE	.37[I,C,P] ns	5%		
						Time to Complete Test on AE	.33[I,C,P] ns	12%		
Military Training	Sonar Maintenance	Tutorial on Simulated Equipment	III	8Exp 8Ctrl	IVD and AE vrs. AE only	Test on AE Procedure I	.29[I,C,P] $p<.05$	39%	See next reference	Williams and Harold (1985)
						Time to Complete Procedure I	.75[I,C,P] $p<.001$	40%		
						Test on AE Procedure II	na ns	33%		
						Time to Complete Procedure II	2.27[I,C,P] $p<.001$	28%		
Same	Same	Same	Same	na	Same	15 year life-cycle costs	na	na	.05 (II and OS)	Green, Beger, and Dunlap (1986)

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Notes Concerning Effect Size:
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C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
Military Training	Interpersonal Skills	Simulated Interpersonal Situations with Tutorial Feedback	III	30Exp1 31Ctrl1 29Ctrl2	IVD(Exp) vrs Role Play (Ctrl1) vrs Programmed Text(Ctrl2)	Content Test1 (Verbal Abuse)	ANOVA ns		1.1	Schroeder, Dyer, Czerny, Youngling, and Gillotti (1986)
				30Exp 31Ctrl	IVD vrs Role Play		.53[I,C,K] ns	19%		Also
				30Exp 29Ctrl	IVD vrs Prog. Text		.31[I,C,K] ns	10%		Schroeder, Hall, and Morey (1985)
					IVD vrs Role Play vrs Prog. Text	Content Test2 (Taking Charge)	ANOVA ns			
					IVD vrs Role Play		.85[I,C,K] ns	25%		
					IVD vrs Prog. Text		.61[I,C,K] ns	29%		
					IVD vrs Role Play vrs Prog. Text	Content Test3 (Meeting the Troops)	ANOVA ns			
					IVD vrs Role Play		-.26[I,C,K] ns	-11%		
					IVD vrs Prog. Text		.05[I,C,K] ns	1%		

Notes Concerning Effect Size:
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C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
					IVD vrs Role Play vrs Prog. Text	Content Test4 (Performance Counseling)	ANOVA ns			
					IVD vrs Role Play		$-.17^{I,C,K}$ ns	-6%		
					IVD vrs Prog. Text		$.74^{I,C,K}$ ns	33%		
					IVD vrs Role Play vrs Prog. Text	Content Test5 (Insubordination)	ANOVA $p<.05$			
					IVD vrs Role Play		$1.12^{I,C,K}$ $p<.05$	43%		
					IVD vrs Prog. Text		$.97^{I,C,K}$ $p<.05$	38%		
					IVD vrs Role Play vrs Prog. Text	Content Test6 (Personal Crisis)	ANOVA ns			
					IVD vrs Role Play		$-.45^{I,C,K}$ ns	-12%		
					IVD vrs Prog. Text		$-.16^{I,C,K}$ ns	-6%		

Notes Concerning Effect Size:
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C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
Military Training	Helicopter Maintenance (Hydraulics)	Tutorial on Simulated Equipment	III	36Exp 35Ctrl	Compulsory Independent Study with vrs without IVD	Paper Test of of Course Knowledge	.48 [I,C,K] $p<.05$	4%	na	Malec and Luszczak (1987)
						Performance Test Using Training Device	.14 [I,C,P] ns	2%		
Industrial Training	CPR Recertification Training for Registered Nurses	Simulation	III	15Exp 14Ctrl	IVD vrs Lecture (Acute Care)	Knowledge Test	-1.14 [I,S,K] ns	-4%	.61 (OS)	Aukerman (1986)
				14Exp 14Ctrl	IVD vrs Lecture (Non-Acute Care)	Knowledge Test	.00 [I,S,K] ns	0%		
				15Exp 14Ctrl	IVD vrs Lecture (Acute Care)	Skill Test	-.07 [I,S,P] ns	-1%		
				14Exp 13Ctrl	IVD vrs Lecture (Non-Acute Care)	Skill Test	.07 [I,S,P] ns	1%		
Industrial Training	Communication Circuit Maintenance	Tutorial with Equipment Simulation	III	10Exp1 10Exp2 12Ctrl	IVD(Exp1) vrs Classroom(Exp2) vrs On-Job Trng (Ctrl)				na	North (1988)

Notes Concerning Effect Size:
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C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
					IVD vrs Classroom	Equipment Knowledge	.75 I,C,K p<.05	20%		
					IVD vrs On-Job Trng		1.42 I,C,K p<.001	58%		
					Classroom vrs On-Job Trng		.77 p<.05	31%		
Industrial Training	Handling of Hazardous Materials	Tutorial	III	105Exp 104Ctrl	IVD vrs Videotape	Errors on Content Test	1.10 I,T,K P<.001	47%	na	Bosco and Wagner (1988)
Higher Education	Biology "Development of Living Things"	Tutorial	III	25Exp 24Ctrl	IVD vrs Lecture (Student Volunteers)	Biology Knowledge (Objective Test)	.27 I,T,K ns	8%	na	Bunderson, Baillio, Olsen, Lipson, and Fisher (1984)
						Biology Knowledge (Short Answer Test)	.93 I,T,K p<.05	73%		Also in Bunderson, Olsen, and Baillio (1981)
						1 Wk Retention (Objective Test)	.29 I,T,K ns	6%		
						1 Wk Retention (Short Answer Test)	.53 I,T,K ns	36%		

Notes Concerning Effect Size:
I -- Included in Effect Size Overview Statistics; T -- Tutorial Approach only; S -- Simulation approach only;
C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
						Learning Time	.60[I,T,K] ns	32%		
				28Exp 25Ctrl	IVD vrs Lecture (Utah) (Random Assignment)	Biology Knowledge (Objective Test)	.88[I,T,K] $p<.05$	18%	na	
						Biology Knowledge (Short Answer Test)	.58[I,T,K] $p<.05$	37%		
						Learning Time	2.12[I,T,K] $p<.05$	44%		
				24Exp 73Ctrl	IVD vrs Lecture (Texas) (Random Assignment)	Biology Knowledge (Objective Test)	.45[I,T,K] $p<.05$	6%	na	
						Biology Knowledge (Short Answer Test)	.59[I,T,K] $p<.05$	17%		
						Learning Time	1.13[I,T,K] $p<.05$	32%		

Notes Concerning Effect Size:
I -- Included in Effect Size Overview Statistics; T -- Tutorial Approach only; S -- Simulation approach only;
C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
Higher Education	Foreign Language (Beginning French)	Tutorial	I,I	26Exp1 26Exp2 26Ctrl	IVD(Exp1) vrs Classroom(Exp2) vrs No Instruction (Ctrl)	Course Knowledge (Multiple Choice Items)	(ANOVA) $p<.001$		na	Crotty (1984)
					IVD vrs Classroom		.09[I,T,K] ns	2%		
					IVD vrs No Instruction		1.50 $p<.05$	31%		
					Classroom vrs No Instruction		1.40 $p<.05$	29%		
					IVD vrs Classroom vrs No Instruction	Course Knowledge (Completion Items)	(ANOVA) $p<.001$			
					IVD vrs Classroom		1.02[I,T,K] $p<.05$	64%		
					IVD vrs No Instruction		2.52 $p<.05$	294%		
					Classroom vrs No Instruction		1.20 $p<.05$	139%		

Notes Concerning Effect Size:
I -- Included in Effect Size Overview Statistics; T -- Tutorial Approach only; S -- Simulation approach only;
C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
Higher Education	Physics "Puzzle of the Tacoma Bridge Collapse"	Simulated Laboratory	III	21Exp 16Ctrl	IVD vrs Laboratory Equipment	Physics Knowledge	$.29^{I,S,K}$ ns	11%	na	Stevens (1984)
				22Exp 19Ctrl		Scientific Attitudes	$.24^{I,S,K}$ ns	2%		
Higher Education	Physics "Puzzle of the Tacoma Bridge Collapse"	Simulated Laboratory	II	18Exp 18Ctrl	IVD vrs Laboratory Equipment	Physics Knowledge (Standing Waves)	-.17 ns	-4%	na	Wankel (1984)
Higher Education	Biology (Respiration)	Simulated Laboratory	III	22Exp 8Ctrl	IVD Lab vrs Traditional Lab	Content Test (Paper)	$-.34^{I,S,K}$ ns	-8%	4.49 (II) .02 (OS)	Davis (1985)
	Biology (Climate and Life)			22Exp 25Ctrl	Same	Same	$.83^{I,S,K}$ $p<.01$	23%	na	
Higher Education	Public Health (Smokeless Tobacco)	Tutorial	III	42Exp1 61Exp2 43Exp3 59Ctrl	IVD(Exp1) vrs Individual Tape (Exp2) vrs Group Tape(Exp3) vrs No Instruction (Ctrl)	Knowledge Test	(ANOVA $p<.001$)		na	Levenson, Morrow, and Signer (1985)
					IVD vrs Individual Tape		$.96^{I,T,K}$ $p<.01$	18%		
					IVD vrs Group Tape		$1.32^{I,T,K}$ $p<.01$	32%		

Notes Concerning Effect Size:
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C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
					IVD vrs No Instruction		.66 $p<.01$	104%		
					Individual Tape vrs Group Tape		.50 $p<.01$	12%		
					Individual Tape vrs No Instruction		1.86 $p<.01$	73%		
					Group Tape vrs No Instruction		1.38 $p<.01$	54%		
Higher Education	Chemistry	Tutorial with Simulated Laboratory	II	58Exp 54Ctrl	IVD vrs Videotape	Course Knowledge	.47[I,C,K] $p<.05$	56%	na	Russell, Staskun, and Mitchell (1985)
				57Exp 55Ctrl		Graphical Analysis	.30[I,C,K] ns	10%		
Higher Education	Chemistry (Kinetics and Equilibrium)	Tutorial with Simulated Laboratory	III	26Exp 23Ctrl	IVD+Lab vrs Lab only	Chemistry Knowledge (Lab Reports)	.69[I,C,K] $p<.05$	17%	na	Smith, Jones, and Waugh (1986)
				21Exp1 17Exp2 49Ctrl	IVD(Exp1) vrs IVD+Lab (Exp2) vrs Lab only (Ctrl)	Course Knowledge	(ANOVA) $p<.001$		na	
					IVD vrs Lab only		1.08[I,C,K] $p<.05$	40%		
					IVD+Lab vrs Lab only		.94[I,C,K] $p<.01$	34%		

Notes Concerning Effect Size:
I -- Included in Effect Size Overview Statistics; T -- Tutorial Approach only; S -- Simulation approach only;
C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
					IVD vrs IVD+Lab		.19[I,C,K] ns	4%		
Higher Education	Chemistry (Kinetics and Equilibrium)	Tutorial with Simulated Laboratory	III	25Exp 27Ctrl	IVD vrs Lab	Course Knowledge	.66[I,C,K] $p<.05$	22%	na	Jones (1987)
Higher Education	Public Health (CPR Instruction)	Simulation	III	48Exp 51Ctrl	IVD vrs Classroom Instruction	Course Knowledge	.35[I,S,K] ns	2%	na	Lyness (1987)
						Performance (Single Rescuer)	.39[I,S,P] ns	47%		
						Performance (Two Rescuer)	.23[I,S,P] ns	19%		
						Performance (Obstructed Airway #1)	.41[I,S,P] $p<.05$	23%		
						Performance (Obstructed Airway #2)	.80[I,S,P] $p<.05$	63%		
						Performance (Obstructed Airway #3)	.67[I,S,P] $p<.05$	59%		

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C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
						Performance (Infant)	-.27[I,S,P] ns	-23%		
						Performance (Infant Obstructed Airway #1)	-.31[I,S,P] ns	-12%		
						Performance (Infant Obstructed Airway #2)	.08[I,S,P] ns	6%		
Higher Education	Foreign Language (Beginning Spanish)	Tutorial	III	23Exp1 23Exp2 23Exp3 23Ctrl	IVD Linear (Exp1) vrs IVD Segmented (Exp2) vrs IVD Interactive (Exp3) vrs Irrelevant Instruction(Ctrl)	Course Knowledge	(ANOVA) $p<.001$		na	Verano (1987)
					IVD Interactive vrs IVD Segmented		1.41[I,T,K] $p<.001$	33%		
					IVD Interactive vrs IVD Linear		2.49[I,T,K] $p<.001$	58%		
					IVD Interactive vrs Irrelevant Inst.		3.84 $p<.01$	88%		
					IVD Segmented vrs IVD Linear		.80[I,T,K] ns	18%		

Notes Concerning Effect Size:
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C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
					IVD Segmented vrs Irrelevant Inst.		1.80 $p<.05$	41%		
					IVD Linear vrs Irrelevant Inst.		.83 ns	19%		
					IVD Interactive vrs IVD Segmented	Course Knowledge (4 Wk Delay)	.79[I,T,K] $p<.001$	30%		
					IVD Interactive vrs IVD Linear		2.24[I,T,K] $p<.001$	56%		
					IVD Segmented vrs IVD Linear		.82[I,T,K] ns	21%		
					IVD Interactive vrs Irrelevant Inst.		2.06 $p<.001$	51%		
					IVD Segmented vrs Irrelevant Inst.		.68 ns	17%		
					IVD Linear vrs Irrelevant Inst.		-.12 ns	-3%		

Notes Concerning Effect Size:
I -- Included in Effect Size Overview Statistics; T -- Tutorial Approach only; S -- Simulation approach only;
C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 1 (Continued). Studies of Interactive Videodisc Instruction Effectiveness.

Instructional Setting	Instructional Content	Instructional Approach	Disc Level	N	Comparison	Outcome	Effect Size	Percent Impr.	Cost Ratio	Reference
Higher Education	Chemistry (Gas Analysis)	Tutorial with Simulated Laboratory	III	26Exp 22Ctrl	IVD vrs Lab	Spectrometer Usage - Score (3 Wk Delay)	1.08 I,C,P p<.01	69%	na	Jones (1988)
						Spectrometer Usage - Time to Complete (3 Wk Delay)	1.09 I,C,P p<.01	39%		
						Knowledge Test (2 Wk Delay)	.51 I,C,K p<.01	10%		

Notes Concerning Effect Size:
I -- Included in Effect Size Overview Statistics; T -- Tutorial Approach only; S -- Simulation approach only;
C -- Combined Tutorial and Simulation; K -- Knowledge Outcome; P -- Performance Skill Outcome

Table 2. Average Effect Sizes for Tutorial and Simulation Instruction, Knowledge and Performance Outcomes.

	Knowledge Outcomes	Performance Outcomes	Totals
Tutorial Approaches	.97 (N = 22)	(N = 0)	.97 (N = 22)
Simulation Approaches	.05 (N = 11)	.19 (N = 18)	.14 (N = 29)
Combined Approaches	.49 (N = 24)	.55 (N = 20)	.52 (N = 44)
Totals	.59 (N = 57)	.38 (N = 38)	.51 (N = 95)

APPENDIX A

EFFECTIVENESS OF INTERACTIVE VIDEODISC IN ARMY COMMUNICATIONS TRAINING

EXECUTIVE SUMMARY

EFFECTIVENESS OF INTERACTIVE VIDEODISC IN ARMY COMMUNICATIONS TRAINING

Executive Summary

The RAND Corporation

January 1989

As the technical sophistication of military weapon and support systems has increased, the services have sought new ways to use technology to train for more complex tasks. Prominent among new training technologies is Interactive Videodisc (IVD), which links a microcomputer and laser videodisc to provide interactive instruction with high-resolution video displays. This report documents two RAND studies of Army IVD applications, employing rigorous experimental designs and post-experimental performance assessments to evaluate the effects of alternative uses of IVD in Army communications training. RAND report.

BACKGROUND

Defense modernization has brought complex new weapon and support systems into the inventories of the military services. Improvements in military technology, however, bri~g conflicting pressures on the services' training establishments. The growing variety and complexity of many new systems tend to raise skill requirements, leading to pressures for longer and more expensive training courses. At the same time, some operational equipment has become so costly that the training base can at best afford only a few pieces that resemble those actually used in the field. In field units themselves, where equipment is available, it is difficult to assure standardization and quality of training.

Military trainers have begun to respond to such challenges by expanding their use of new computer-based, visually-oriented training devices and simulators. These technologies have the potential to simulate a variety of new equipment, provide individualized yet standardized instruction, engage learners in dynamic problem-solving situations, and provide immediate feedback about performance. Among recent innovations, interactive videodisc technology, which consists of an integrated microcomputer, video display, laser videodisc, and instructional software (termed interactive courseware), represents a new training device with considerable promise.

The U.S. Army Signal Center at Fort Gordon, Georgia, has pioneered the use of IVD systems for training soldiers in a variety of communications-electronics military occupational specialties (MOSs). Signal Center developers of an early IVD system -- a predecessor to the Army's Electronic Information Delivery System, which is being acquired in large numbers starting in Fiscal 1988 -- have hypothesized that school-based IVD training may increase student proficiency and reduce hands-on training requirements for a broad range of specialties. They also believe that IVD systems have potential in field units for refresher and on-the-job training. Demonstration of these hypothesized benefits could affect decisions by the Army and by the other services about purchasing EIDS hardware, developing interactive courseware, and allocating EIDS training systems across various specialties and environments.

The possible benefits of IVD technology are of interest not only to the services, but also to the Office of the Secretary of Defense (OSD), which has oversight responsibility for the efficiency of training. OSD interest in the Signal Center experience, and in the effectiveness of IVD more broadly, has been heightened as the various services have become interested in applications of interactive videodisc technology. However, to date the systematic data needed to assess the potential benefits of IVD have been lacking. To provide such data and to establish a model for future research in this area, RAND undertook a series of studies of IVD in cooperation with the Signal Center and OSD's

Defense Training and Performance Data Center. This report presents the results of these studies and their implications for uses of IVD in military settings.

OBJECTIVES AND APPROACH

The objectives of this study were to develop a methodology for assessing the benefits of innovative training technologies, to apply this methodology to evaluate the effectiveness of an IVD training system used at the Army Signal Center, and to define general conditions for effective use of IVD technology.

Our approach applied principles of controlled experimentation to compare effects of alternative methods used to train equivalent groups of soldiers. We report the results of two studies. In both, the effects of traditional hands-on equipment training (the control condition) are compared with effects of a training regimen using IVD (the experimental condition). The experimental and control groups were formed using a statistical randomization model developed at RAND which provides a close match between groups on such factors as aptitude, educational background, demographic characteristics, and military experience. The training received by each group was carefully monitored, and the effects of alternative training methods were compared using multivariate analysis of objective, training- and job-related performance criteria.

The two studies examine the two most common applications of IVD in the Army: As a device used to *supplement* or augment existing hands-on training, and as a device used *simulate* or replace hands-on equipment training. The first use of IVD increases training opportunity, while increasing costs; the second use of IVD can maintain existing training opportunity, while decreasing costs. These studies provide empirical evidence of IVD effectiveness in the specific MOSs trained, and they point to implications for IVD training policy in many other military settings.

SUPPLEMENTARY TRAINING WITH IVD: MOS 31M

The initial experiment evaluated the effects of IVD on student proficiency when used as a device to supplement hands-on equipment training in MOS 31M, Multichannel Communications Equipment Operator. The experimental training took place during two weeks of the course when students learned to install "low-capacity" radio equipment (AN/TRC-145). The experiment lasted seven months and covered 428 active-duty trainees who were assigned to one of two groups. The control group received hands-on training at installation using only radio assemblages, while the experimental group received both hands-on training with radio assemblages and IVD training. Each group had an equal number of radio assemblages available (normally 10 assemblages for a class of up to 25 students). In the experimental group, the IVD provided an additional eight training positions to help make up the difference between the numbers of trainees and assemblages.

Several weeks later, the performance of each trainee at assemblage installation was assessed using the Reactive Electronic Equipment Simulator (REES), a high-fidelity, computer-controlled facility that contained the pertinent radio assemblages. The REES computer provided data on the accuracy with which trainees accomplished the installation, as well as the amount of time and effort required to successfully install the radio assemblage. Trainees' job knowledge was also assessed using a written examination, which contained elements of job knowledge that were trained, as well as measures of trainees' attitudes toward the training that they received.

The research hypothesis in this study was that IVD use would increase the efficiency of training, while improving student proficiency. Results showed that the IVD was extensively implemented in the experimental classrooms; the addition of IVD to the classroom led to a 45 percent increase in time spent practicing installation of radio assemblages. Thus, these students received increased training opportunity without lengthening their overall amount of time in the course. In this respect, the use of IVD allowed instructors to make more efficient use of student time.

IVD training also increased soldier proficiency, as assessed in the high-fidelity simulator. Regression analyses showed that supplemental IVD training caused statistically significant reductions in the time needed to install the radio equipment, the number of trials (amount of effort) needed to accomplish the installation, and the likelihood of a student error during the installation process. These reductions were modest, however, ranging between 10 and 20 percent.

SUBSTITUTION TRAINING WITH IVD: MOS 31Q

The second experiment examined the effects of substituting IVD technology for more expensive equipment in MOS 31Q, Tactical Satellite/Microwave Systems Operator. This experiment, lasting ten months and encompassing 336 trainees, focused on training the alignment and adjustment of complex and expensive tropospheric scatter (TROPO) radio assemblages. The approach held the amount of training opportunity constant, while varying the resources used for training. Students were assigned to one of two groups: Half carried out exercises in a classroom equipped with 7 TROPO radios and 8 closely-related line-of-sight (LOS) radios, while the other half carried out similar exercises in a classroom that contained only one of each type of radios but had eight IVD units -- a much less expensive complement of training devices.

Immediately after the training, we assessed the performance of each trainee using a hands-on test based on the Army Soldier's Manual, including three relevant tasks (IF gain and AGC alignment, and squelch adjustment). The hands-on tests were administered by objective assessors, trained and monitored by RAND, who were unaware of how each soldier had been trained. For each test, we determined whether the trainee could accomplish each of the tasks within the respective Army time standard, and we recorded errors made during task performance. Trainees also received a written test providing measures of task knowledge and attitudes toward the training that they received.

For this study the research hypothesis was that students would be equally proficient at the tasks, whether they were trained under the traditional equipment-only regimen or under the alternative regimen in which IVD was used at a substantial saving in training resources. Our analyses confirm the hypothesis for measures of proficiency and job knowledge. As an illustration, we summarize results for performance at the IF Gain alignment, the most difficult of the tasks. The results show that students used IVD extensively in the experimental classroom, accomplishing 58 percent of their training sessions on IVD. Students in the control group received approximately the same number of training sessions, but of course 100 percent of their training was done on actual equipment. Despite this substitution, the performance of the groups on the hands-on test was statistically indistinguishable.

Our analyses show similar results for student performance in AGC alignment and squelch adjustment: Ability to accomplish the task was the same, whether students were trained with actual equipment or with a mix of IVD and actual equipment. However, for these tasks the IVD-trained students appeared slightly more likely to make procedural errors, and they were less satisfied with the training they received.

CONCLUSIONS

The results of these experimental studies show that IVD technology can be beneficial in its two most common types of application: as a supplement to existing training or as a substitute for more expensive training resources. In MOS 31M, the addition of IVD provided increased training opportunity and caused improvements in measures of subsequent task proficiency[1]. In MOS 31Q, the replacement of some equipment training with IVD training did not diminish students' ability to perform the relevant tasks. These studies thus confirm hypothesized benefits of IVD technology for the applications that we examined.

At the same time, however, information collected in both studies suggested some important conditions that may affect when and where one chooses to use IVD. In MOS 31M, our data showed that most trainees received ample hands-on training opportunity, even in the control group where instructors perceived an equipment shortage; in fact, nearly all

[1] Other research studies suggest that the additional practice provided by such training technologies can permit a reduction in the allotted training time.

trainees were eventually able to perform the installation successfully. We speculated (though without strong statistical evidence) that frequent practice on real equipment had given most students a fairly high level of basic proficiency, which may have limited the benefits that could be gained by adding IVD. If correct, this suggests an important criterion for using IVD as a supplement to existing training resources: Supplementation is most likely to pay off in those situations where opportunities to train are more scarce, the difficulty of the task is more demanding, and existing proficiency is more unsatisfactory.

The 31Q experiment confirmed that substituting IVD in place of hands-on training is an attractive and feasible method of reducing equipment costs. However, there are likely to be limitations to such substitution, and the 31Q experience points to them. Even though the IVD-trained students in the 31Q study were equally capable of accomplishing their tasks, they were slightly more likely to make certain procedural errors, and they expressed less satisfaction with training. We believe that these differences may arise from the extreme contrast in hands-on opportunity experienced in the two groups; the equipment-trained students enjoyed ample practice on real radio assemblages, while the IVD-trained group had only brief exposure to actual equipment. If true, this suggests that certain minimum levels of hands-on training may be required to ensure competency and self-confidence among trainees.

Thus the results of both experiments indicate that IVD can be an effective element of training, and they point to some conditions for using the technology wisely. Given the costs of acquiring IVD systems and developing supporting interactive courseware, however, its application seems best encouraged in those circumstances where it can be used to greatest potential: To save training costs as part of a training resource mix, or to provide additional training where improvements in proficiency are needed and the additional costs can be justified.

APPENDIX B

LIST OF ORGANIZATIONS CONTACTED

ORGANIZATIONS CONTACTED

ABC Technologies International, Inc.
805 DuPont Street
Suite 4
Bellingham, WA 98225

Access Network
295 Midpark Way, S.E.
Calgary, Alberta
Canada T2X 2A8

Actronics
810 River Avenue
Pittsburgh, PA 15212

Advanced Technology, Inc.
12005 Sunrise Valley Drive
Reston, VA 22091

Air Force Communication Command
1872 SCHS/TUV
Keesler Air Force Base, MS 39534-6340

Air Force Human Resource Laboratory/MOMJ
Brooks Air Force Base, TX 78235-5601

Air Training Command
HQ ATC XPCTR
Randolph Air Force Base, TX 78150

Air Training Command
3300 Technical Training Wing
Keesler Air Force Base, MS 39534-5000

Alamo Learning Systems
37000 Grand River
Farmington Hills, MI 48024

The Alive Center
1248 Weathervane Lane
Akron, OH 44313

Allen Communication
140 Lakeside Plaza II
5225 Wiley Post Way
Salt Lake City, UT 84116

Alta Association
436 E. 3400 N.
Logan, UT 84321

American Language Academy
11426 Rockville Pike, Suite 200
Rockville, MD 20852

American Journal of Nursing Company
555 W. 57th Street
New York, NY 10019

American Society for Training and Development
1630 Duke Street
P.O. Box 1443
Alexandria, VA 22313

Andersen Consulting
33 W. Monroe
Chicago, Il 60603

Andersen Consulting
901 Main Street - Suite 5600
Dallas, TX 75202

Annenberg/Corporation for Public
Broadcasting Project
1111 Sixteenth Street, N.W.
Washington, DC 20036

Apple Computer
Multi-Media Group
3220 Sacramento
San Francisco, CA 94115

Applied Interactive Technologies, Inc.
621 Lakeland East Drive
Jackson, MS 39208

Applied Learning International
(Deltak, Advanced Systems, Inc.)
EAST-WEST Technological Center
1751 West Diehl Road
Naperville, IL 60540-9075

Applied Science Associates
Metro II, Suite 900
8201 Corporate Drive
Landover, MD 20785

Army Research Institute
Training Research Laboratory
5001 Eisenhower Avenue
Alexandria, VA 22314

Army Research Institute - Monterey Field Unit
P.O. Box 5787
Presidio of Monterey, CA 93944

Arthur Andersen and Company
1666 K Street, N.W.
Washington, DC 20006

Arthur Andersen and Company
Research and Development
1405 N. Fifth Avenue
St. Charles, IL 60174

Assessment Designs International
2500 Maitland Center Parkway
Maitland, FL 32751

Association of Developers of Computer-Based Instruction
International Headquarters
Miller Hall 409
Western Washington University
Bellingham, WA 98225

AT&T Corporate Training
100 Southgate Parkway
Morristown, NJ 07960

Bain and Company
2 Copley Place
Boston, MA 02116

Baker Videoactive
1501 Walnut Street
Philadelphia, PA 19102

BBC Elstree Center
Clarendon Road
Borehamwood
Herts WD6 165
U.K.

Beckwith Custom Communications Company
147 Bell Street
Chagrin Falls, OH 44022

Bethlehem Steel Corporation
Videodisc Team
Room 1268 Martin Tower
Bethlehem, PA 18016

Bloomsburg University
Department of Mathematics
McCormick Building
Bloomsburg, PA 17815

BNA Communications, Inc.
9439 Key West Avenue
Rockville, MD 20850-3396

Boeing Military Airplane
P.O. Box 1470
Huntsville, AL 35807

Boeing Military Airplane
P.O. Box 7730
Wichita, KS 67277

Brighton Polytechnic
Telsoft Interactive Video Project
Falmer Brighton BN1 9PH
U.K.

Brown University
Department of Anthropology
Providence, RI 02912

Butler-Raila and Company
298A Highland Avenue
Somerville, MA 02144

California State Polytechnic University
Department of Management and Human Resources
3801 W. Temple Avenue
Pomona, CA 91768

California State University - Chico
Communication Design
Chico, CA 95929-0504

California State University - Sacramento
Division of Nursing
6000 "J" Street
Sacramento, CA 95819

Carnegie-Mellon University
Software Engineering Institute
Pittsburgh, PA 15213

Caterpillar
P.O. Box 787
York, PA 17405

Catharon Productions Inc.
Route 1, Box 8
Ghent, NY 12075

CEIT Systems, Inc.
225 Charcot Avenue
San Jose, CA 95131

Central Intelligence Agency
Office of Training and Education
ITD/CBT
Washington, DC 20505

Central Piedmont Community College
"Project Ready"
P.O. Box 35009
Charlotte, NC 28235

Children's Television Workshop
1 Lincoln Plaza
New York, New York 10023

Cincinnati Milacron Marketing Company
(CinTraining Training Systems)
4701 Marburg Avenue
Cincinnati, OH 45209

Clemson University
Agricultural Engineering Department
115 McAdams Hall
Clemson, SC 29634-0357

College of Aeronautics
La Guardia Airport
Flushing, NY 11371

Combustion Engineering
1000 Prospect Hill Road
Windsor, CT 06095

Commission on Peace Officers Standards
and Training
1601 Alhambra Blvd.
Sacramento, CA 95816-7083

Competence Assurance Systems
University Park at M.I.T.
26 Landsdowne Street, Suite 500
Cambridge, MA 02139-4234

Computer Sciences Corporation
813 DiLigence Drive
Suite 110
Newport News, VA 23606

Comsell, Inc.
500 Tech Parkway
Atlanta, GA 30313

Conceptual Systems, Inc.
1100 Wayne Avenue, 12th Floor
Silver Spring, MD 20910

Convergent Technologies Associates
97 Devonshire Drive
New Hyde Park, NY 11040

Corporate Resource Associates, Inc.
333 Twin Dolphin Drive, Suite 225
Redwood City, CA 94065

Crawford Communications
500 Plasters Avenue
Atlanta, GA 30324

Creative Video/Floyd Design
1465 Northside Drive - Suite 110
Atlanta, GA 30318

Defense Intelligence College
Research Center
DIA/DIC-R
Washington, DC 20340-5485

Defense Language Institute
Foreign Language Center
Attn: ATFL-VPT
Presidio of Monterey, CA 93944-5006

Digital Equipment Corporation
12 Crosby Drive
Bedford, MA 01730

Digital Equipment Corporation
146 Main Street
Maynard, MA 01754

Discworks, Inc.
42 Crescent Street
Cambridge, MA 02138

Diversified Data Resources, Inc.
6609 Rosecroft Place
Falls Church, VA 22043

Eagle Technology, Inc.
950 N. Orlando Avenue
Winter Park, FL 32789

Eastman Kodak Company
343 State Street
Rochester, NY 14650

Education TURNKEY Systems
256 N. Washington Street
Falls Church, VA 22046-4549

Educational Activities, Inc.
P.O. Box 392
Freeport, NY 11520

Educational Data Systems
22720 Michigan Avenue
Dearborn, MI 48124

Educational Testing Service
Princeton, NJ 08541

Edudisc, Inc.
1400 Tyne Blvd.
Nashville, TN 37215

EECO, Incorporated
1601 E. Chestnut
Santa Ana, CA 92702-0659

EER Systems
3290 Progress Drive
Orlando, FL 32826

Essex Corporation
1040 Woodcock Road - Suite 227
Orlando, FL 32803

European Institute of Education and
Social Policy
% Universite de Paris IX - Dauphine
75116 Paris
France

Falcon Software
P.O. Box 102
Wentworth, NH 03282

Federal Aeronautics Administration
(FAA) Academy (ACC 912)
Mike Monroney Aeronautical Center
P.O. Box 25082
Oklahoma City, OK 73125

Federal Express
2856 Directors Cove
Memphis, TN 38131

Federal Law Enforcement Training Center
Glenco, GA 31524

First National Bank of Chicago
1 N. State Street - Suite 0392
Chicago, IL 60670

FlightSafety International Communication
Systems
632C Bedford-Euless Road
Hurst, TX 76053

Florida Department of Health and
Rehabilatative Services
1311 Winewood Blvd. - Bldg 5, Room 131
Tallahassee, FL 32301

Florida State University
College of Education
215 Stone Building
Tallahassee, FL 32306

Ford Motor Company
World Headquarters
The American Road
Dearborn, MI 48121-1899

Ford Parts and Service
Training Department
3000 Sheaffer Road
Dearborn, MI 48121

Forhan and Wakefield Group
265 Post Road West
Westport, CT 06880

Fuld Institute for Technology in Nursing
Education (FITNE)
28 Station Street
Athens, OH 45701

Gant Associates
222 Third Street - Suite 2242
Cambridge, MA 02142

General Electric Aircraft Engineering
Educational Services Center
Mail Drop E199
1 Neumann Way
Cincinnati, Ohio 45215

George Washington University
Department of Management Science
Monroe Hall - Room 203
2115 "G" Street, N.W.
Washington, DC 20052

Georgetown University School of Medicine
TIME Project
Kober-Cogan Building
3800 Reservoir Road, N.W.
Washington, DC 20007-2197

Gery Associates
5 Brookman Drive
P.O. Box 851
East Otis, MA 01029-0851

Global Information Systems Technology, Inc.
1800 Woodfield Drive
Savoy, IL 61874-9505

Golle & Holmes Custom Education
1600 W. 82nd Street
Minneapolis, MN 55431

GPN
P.O. Box 80669
Lincoln, NE 68501

GTE Corporation
1 GTE Place
Thousand Oaks, CA 91362-3811

GTE Directories Corporation
GTE Place West Airfield Drive
P.O. Box 619810
D/FW Airport, TX 75261

Hane Industrial Training, Inc.
120 South 7th Street
P.O. Box 3165
Terre Haute, IN 47803

Hansen Training Systems, Inc.
1981 Abbotsford Drive
Barrington, IL 60010-5560

Harvard University Law School
Interactive Video Project
Cambridge, MA 02138

Harvard University
Graduate School of Education
Cambridge, MA 02138

Harvard University
Graduate School of Education
Interactive Technology Office
Cambridge, MA 02138

Health EduTech
7801 E. Bush Lake Road
Minneapolis, MN 55435

Hoffman Educational Systems
1720 Flower Avenue
Duarte, CA 91010

Hope Reports, Inc.
1600 Lyell Avenue
Rochester, NY 14606

Hoxworth Blood Center
3231 Burnet Avenue
Cincinnati, OH 45267-0055

Hughes Associates
2730 University Blvd. West - Suite 902
Wheaton, MD 20902

Hughes Training Systems, Inc.
2200 Arlington Downs Road
Arlington, TX 76011

IBM Corporation
3301 Windy Ridge Parkway
Marietta, GA 30067

IBM Corporation
PO.O. Box 2150
Atlanta, GA 30055

IBM Corporation
6905 Rockledge Drive
Bethesda, MD 20817

IBM Corporation
Thomas J. Watson Research Laboratory
White Plains, NY 10604

IBM - U.S. Education
500 Columbus Road
Thornwood, NY 10594

ICON Associates, Inc.
72 South La Grange Road, Suite 8
La Grange, IL 60525

Image Premastering Services, Ltd.
1781 Prior Avenue North
St. Paul, MN 55113

Imedia International Inc.
M.I.T. Branch
P.O. Box 347
Cambridge, MA 02139

IMSATT Corporation
Suite 101
Falls Church, VA 22046

Indiana University
School of Education
Education Technology Services
Education 325
Bloomington, IN 47401

Industrial Training Corporation
13515 Dulles Technology Drive
Herndon, VA 22070

Info-Disc Corporation
4 Professional Drive
Suite 134
Gaithersburg, MD 20879

Info Tech
4040 E. Bijou Street
Colorado Springs, CO 80909

Information Technology Group
9017 Shady Grove Court
Gaithersburg, MD 20877

The Institute of Electrical and
Electronic Engineers
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331

Institute for Interactive Learning
4205 - 148th Avenue, N.E. - Suite 202
Bellvue, WA 98007

Instructional Design International
1775 Church Street, N.W.
Washington, DC 20036

Instructional Science and Development
4918 N. Harbor Drive
Suite 201
San Diego, CA 92106

Intell
201 Washington Road
P.O. Box CN5325
Princeton, NJ 08543

Intelligent Images
A Division of DaRox Corp.
5510 Morehouse Drive
San Diego, CA 92121

Intellisance Cdex Corporation
1855 Lundy Avenue
San Jose, CA 95131

Interactive Image Technologies
49 Bathurst Street - Suite 401
Toronto M5V 2P2
Canada

Interactive Instructional Systems, Inc.
2 Gateway Center
14 West
Pittsburgh, PA 15222

Interactive Learning Systems
25 Sylvan Road South
Westport, CT 06880

Interactive Medical Communications
100 Fifth Avenue
Waltham, MA 02154

Interactive Performance Systems
The John H. Harland Company
(Interactive Financial Learning Systems)
Box 105250
Atlanta, GA 30348

Interactive Technologies Corporation
9625 Black Mountain Road
San Diego, CA 92126

Interactive Training Incorporated
See Education Data Systems

Interactive Training Systems
See Spectrum Interactive

Interactive Video Industry Association
5929 Lee Highway
Arlington, VA 22207

Inter-ad, Inc.
52 Marway Circle
Rochester, NY 14624

InterCom, Inc.
302 E. John Street
Champaign, IL 61820

International Interactive Communications Society
2120 Steiner Street
San Francisco, CA 94115

International Television Association
6311 N. O'Connor Road
Irving, TX 75039

ISC Educational Systems, Inc.
3700 Electronics Way
P.O. Box 3040
Lancaster, PA 17604-3040

Ixion, Inc.
1335 N. Northlake Way
Seattle, WA 98103

Jarvis Associates
10320 South 1435 West
South Jordan, UT 84065

Jenson Publications Video Products Division
2770 S. 171st Street
New Berlin, WI 53151-0482

Jeppesen Sanderson, Inc.
55 Inverness Drive East
Englewood, CO 80112-5498

Kent State University
College of Education
Industrial Resources Center
Kent, OH 44242

Keyboard Productivity, Inc.
6035 Bristol Parkway
Culver City, CA 90230

Kinton, Inc.
5707 Seminary Road
Bailey's Crossroads, VA 22041

Leadership Studies, Inc.
230 W. Third Avenue
Escondido, CA 92025

Learncom
A Division of Sandy Corporation
215 First Street
Cambridge, MA 02142

Learning International
P.O. Box 10211
Stamford, CT 06904-9926

Learnstar, Inc.
24333 Southfield Road, Suite 205
Southfield, MI 48075

Linguistic Systems, Inc.
116 Bishop Allen Drive
Cambridge, MA 02139-0901

Management Development Services, Inc.
73 East Hanover Avenue
Morristown, NJ 07960-2432

Mankind Research Foundation
1315 Apple Avenue
Silver Spring, MD 20910-8276

Marplex, Inc.
71 N. Main Street
Chagrin Falls, OH 44022

Massachusetts Institute of Technology
Audience Research Facility
Cambridge, MA 02139

Massachusetts Institute of Technology
Department of Psychology
Cambridge, MA 02139

Massachusetts Mutual Life Insurance Company
Springfield, MA 01111

Mastertask Training Systems
V-Tip, Inc.
407 Green Street
Rockford, IL 61105-0337

MATROX Electronic Systems
1055 St. Regis Blvd
Dorval, Quebec
Canada

McDonnell Douglas Training
8201 Greensboro Drive
McLean, VA 22102

MECC
3490 Lexington Avenue, North
St. Paul, MN 55126

The Media Exchange
217 S. Payne Street
Alexandria, VA 22314

Media Learning Systems
120 W. Colorado Blvd.
Pasadena, CA 91105

MedicalDisc Reporter
6471 Merritt Court
Alexandria, VA 22312

Meta Media
20251 Century Blvd.
Germantown, MD 20874

Metropolitan Police Training Center
PT8
Training Support Services
Peel Center
Aerodrome Road
London NW9 5JE
U.K.

Metrowest Communications Group
P.O. Box 3308
Framingham, MA 01701

Miami-Dade Community College
Product Development and Distribution
11011 S.W. 104th Street
Miami, FL 33176

Microworx, Inc.
13911 Ridgedale Drive, #461
Minnetonka, MN 55343

MindBank, Inc.
736 W. Ingomar Road - Suite 220
P.O. Box 60
Ingomar, PA 15127

Mirror Systems, Inc.
2067 Massachusetts Avenue
Cambridge, MA 02140

MITEC
11767 Bonita Avenue
Owings Mills, MD 21117

National Cryptologic School
Ft. Meade, MD 20755

National Interactive Video Center
24-32 Stephenson Way
London NW1 2HD
U.K.

National Library of Medicine
Lister Hill Center
8600 Rockville Pike
Bethesda, MD 20894

National School Board Association
1600 Duke Street
Alexandria, VA 22314

National Science Center for
Communications Electronics
P.O. Box 1648
Augusta, GA 30903

National Security Agency
Attn: E33
Ft. Meade, MD 20785-6000

Naval Training Systems Center
Code 10
Orlando, FL 32826

Naval Training Systems Center
Code 113
Orlando, FL 32826-3224

Navy Personnel Research and Dev. Center
San Diego, CA 92152

Nebraska Interactive Video
P.O. Box 4707
Lincoln, NE 68504

Nebraska Videodisc Group
P.O. Box 8311
Lincoln, NE 68501

New Mexico State Unversity
Agricultural Information Center
Las Cruces, NM 88003

New Mexico State University
College of Education
Las Cruces, NM 88003

Newport News Ship Building
2711 S. Jefferson Davis Highway - Suite 1100
Arlington, VA 22202

North Communications
3030 Pennsylvania Avenue
Santa Monica, CA 90404

Northrop Corporation - Aircraft Division
1 Northrop Avenue - 1560/40
Hawthorne, CA 90250-3277

Office of Technology Assessment/SET
U.S. Congress
Washington, DC 20510-8025

Omni Com Associates
407 Coddington Road
Ithica, NY 14850

Online Computer Systems, Inc.
20251 Century Blvd.
Germantown, MD 20874

Optical Data Corporation
30 Technology Drive
P.O. Box 4919
Warren, NJ 07060

Oregon State University
Media Laboratory
School of Education
Corvallis, OR 97331

Paperback Video Publishing, Inc.
29 Broadway
New York, NY 10006

Pennsylvania State Unviversity
Instructional Systems Department
246 Chambers
University Park, PA 16802

Perceptronics, Inc.
Training and Simulation Systems Division
2122 Erwin Street
Woodland Hills, CA 91367

Performax
1720 Post Road East
Westport, CT 06880

Person-System Integration
2401 Huntington Avenue
Alexandria, VA 22303-1531

Phoenix Interactive Design
470 Ridout Street North
London ONT 2P7
Canada

Pioneer
1058 E. 230th Street
Carson, CA 90745

Pioneer
600 E. Crescent Avenue
Upper Saddle River, NJ 07458

PJV Inc.
    See the Alive Center

Pratt & Whitney
400 Main Street - MS 117-34
East Hartford, CT 06108

Pratt & Whitney
P.O. Box 109600
West Palm Beach, FL 33410

Professional Training Systems, Inc.
400 Colony Square - Suite 1525
1201 Peachtree Street, N.E.
Atlanta, GA 30361

Rand Corporation
1700 Main Street
P.O. Box 2138
Santa Monica, CA 90406-2138

Regency Systems, Inc.
3200 Farber Drive
Champaign, IL 61821-3578

RJO Enterprise
4550 Forbes Blvd.
Lanham, MD 20706

Reynolds and Reynolds
800 Germantown Street
Dayton, OH 45407

San Diego State University
Department of Educational Technology
San Diego, CA 92182-0311

San Jose State University
Department of Instructional Technology
San Jose, CA 95192

Sandy Corporation
1500 W. Big Beaver Road
Troy, MI 48084

Science Research Associates, Inc.
155 North Wacker Drive
Chicago, IL 60606

Scientific Systems Incorporated
1 Alewife Place
Cambridge, MA 02140

Stanton C. Selbst, Inc.
7-11 S. Broadway
White Plains, NY 10601

Seville Training
A Division of FlightSafety
2445 Gateway Drive
Irving, TX 75063

Sony Corporation of America
Intelligent Systems Group
Sony Drive
Park Ridge, NJ 07656

Source Interactive
1181 South Parker Road
Denver, CO 80231

Southern Oregon State College
Education Department
Ashland, OR 97520

South-Western Publishing Company
5101 Madison Road
Cincinnati, OH 45227

Spectrum Interactive (ITS, Inc.)
9 Oak Park Drive
Bedford, MA 01730

Stanford University
ACIS/IRIS
Sweet Hall - 3rd Floor
Stanford, CA 94305-3091

State University of New York - Binghamton
Department of Mechanical Engineering
Binghamton, NY 13901

Statistica, Inc.
One Metro Square
51 Monroe Street
Rockville, MD 20850

Synergistic Educational Technology
  Systems, Inc.
4405 Vineland Road
Suite C4
Orlando, FL 32811

Syracuse University
Instructional Design, Development and
Evaluation
330 Huntington Hall
Syracuse, NY 13244

SYSCON
12424 Research Parkway
Suite 390
Orlando, FL 32826

Systems Impact
4400 McArthur Blvd., N.W. - Suite 203
Washington, DC 20007

Tactical Air Command
U.S. Air Force
4400th Maintenance Training Flight (TAC)
Hill Air Force Base, UT 84056-5000

TAPPI
Technology Park
Atlanta, GA 30348

TCT Technical Training, Inc.
599 N. Mathilda Avenue
Sunnyvale, CA 94086

TEAC Corporation of America
7733 Telegraph
Montebello, CA 90640

Tel-A-Train, Inc.
309 N. Market Street
Chattanooga, TN 37405

Tennessee Valley Authority
Skills Development
601 W. Summit Hill Drive
1B31 Old City Hall Building
Knoxville, TN 37902

Texas School Board Association
Texas Learning Technology Group
P.O. Box 2947
Austin, TX 78769-2947

3M Optical Recording
3M Center 223-5S-01
St. Paul, MN 55144

T/K International, Incorporated
663A Market Hill Road
Vancouver, BC V5Z 4B
Canada

TPC Training Systems
Div. of Telemedia, Inc.
310 S. Michigan Avenue
Chicago, IL 60604

TRADOC
ATRC-WGB
TRAC-WSMR
White Sands Missile Range, NM 88002-5502

Training and Development Resources
104 E. Main Street
Durham, NC 27707

The Training Group, Inc.
#202, 4220-98 Street
Edmonton, Alberta T6E 6A1
Canada

Training and Performance Data Center
3280 Progress Drive
Orlando, FL 32826

Training Solutions, Inc.
2314 Lincoln Park West
Chicago, IL 60614

Training Solutions, Inc.
4647 Willis - #106
Sherman Oaks, CA 91403

Uniformed Services University of
the Health Sciences
Center for Interactive Media in Medicine
Department of Military Medicine
4301 Jones Bridge Road
Bethesda, MD 20814

UNISYS Education Center
P.O. Box 1110
Princeton, NJ 08543

United Auto Workers/General Motors
Health and Safety Training Center
29815 John R
Madison Heights, MI 48071

United States Air Force Academy
Department of Foreign Languages
USAF/DFF
Colorado Springs, CO 80840-5701

United States Army Training Support Center
Ft. Eustis, VA 23604-5168

United States Department of Agriculture
3322-S
USDA-ES-CIT
Washington, DC 20025-0900

United States Military Academy
Department of Foreign Languages
West Point, NY 10996

United States Naval Academy
Department of Language Studies
Annapolis, MD 21402-5030

University of Akron
Center for Computer-Based Education
Carroll Hall
Akron, OH 44325

University of Alberta
Instructional Technology Center
B117 Education North
Alberta T6G 2G5
Canada

University of California - Davis
Department of Education
Davis, CA 95616

University of California - Irvine
Department of Education
Irvine, CA 92717

University of Central Florida
Instructional Systems Program
College of Education
Orlando, FL 32816

University of Chicago
Department of Education
5835 S. Kimbark Avenue
Chicago, IL 60637

University of Cincinnati
College of Nursing and Health
3110 Vine Street
Cincinnati, OH 45221-0038

University of Cincinnati
Educational Foundations Department
406 Teachers College - Mail Location 2
Cincinnati, OH 45221

University of Connecticut
School of Nursing
231 Glenbrook Road
U-26
Storrs, CT 06269-2026

University of Delaware
Academic Computing and Instructional
Technology
307 Willard Hall
Newark, DE 19716

University of Georgia
College of Education
Athens, GA 30602

University of Houston
Department of HPER
College of Education
Houston, TX 77004

University of Illinois
Computer-Based Education Research Laboratory
103 S. Mathews Avenue - 252ERL
Urbana, IL 61891-2977

University of Iowa
Weeg Computing Center
100 LC
Iowa City, IA 52242

University of Maryland
Center for Instructional Development and
Education (CIDE)
Center for Adult Education
University Blvd. and Adelphi Road
College Park, MD 20742

University of Miami
Center for Interactive Technology
219 Merrick Building
School of Education
Coral Gables, FL 33146

University of New Mexico
College of Education
Learning Materials Laboratory
Albuquerque, NM 87131

University of North Carolina - Charlotte
College of Education
Department of Curriculum and Instruction
UNCC Station
Charlotte, NC 28223

University of Washington
Health Science Center for Education Resource
Health Science Building - T281 SB56
Seattle, WA 98185

Utah State University
UMC 6800
Technology Division - DCHP
Logan, UT 84322

Vanderbilt University
Corporate Learning Institute
Nashville, TN 37240

Vanderbilt University
Department of Special Education
Nashville, TN 37240

Vanderbilt University
Learning Technology Center
Nashville, TN 37240

Veritech Corporation
37 Prospect Street
East Longmeadow, MA 01028

Video Training Resource, Inc.
7500 West 78th Street
Edina, MN 55435-2889

Videodisc Monitor
P.O. Box 26
Falls Church, VA 22046

Videodiscovery
P.O. Box 85878
Seattle, WA 98145-1878

Virginia Polytechnic Institute
Department of Interactive Design and
  Development
Blacksburg, VA 24061-0530

Wayne State University
Instructional Technology Graduate Program
Room 379
College of Education
Detroit, MI 48202

Western Michigan University
Tate Research Center
College of Education
Kalamazoo, MI 49008

WGBH
Department of Telecommunications
125 Western Avenue
Boston, MA 02134

WICAT Systems
1875 S. State Street
Orem, UT 84057

WICAT Systems
℅ Boeing Aerospace
P.O. Box 3707 MS 2T-85
Seattle, WA 98124

John Wiley & Sons, Inc.
605 Third Avenue
New York, NY 10158

Wilson Learning Corporation
(Wilson Learning Interactive Technology Group)
7500 Flying Cloud Drive
Eden Prairie, MN 55344-3795

Wisconsin Foundation for Vocational Training
and Adult Education Inc.
2564 Branch Street
Middleton, WI 53562

Xerox Corporation
Xerox Square - 15B
100 Clinton Avenue South
Rochester, NY 14644