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EFFECTIVENESS AND COST OF INTERACTIVE VIDEODISC INSTRUCTION IN DEFENSE TRAINING AND EDUCATION

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ABSTRACT

In response to Congressional direction, a quantitative, analytical review (a "meta-analysis") was completed of interactive videodisc instruction applied in Defense training and in the related settings of industrial training and higher education. Over all instructional settings and applications, interactive videodisc instruction was found to improve achievement by about 0.50 standard deviations over less interactive, more conventional approaches to instruction. This improvement is roughly equivalent to increasing the achievement of students at the 50th percentile to that of students currently at the 69th percentile. An improvement of 0.38 standard deviations was observed across 24 studies in military training (roughly an increase from 50th to 65th percentile achievement). An improvement of 0.69 was observed across 14 studies in higher education (roughly an increase from 50th to 75th percentile achievement). Interactive videodisc instruction was more effective the more the interactive features of the medium were used. It was equally effective for knowledge and performance outcomes. It was less costly than more conventional instruction. Overall, interactive videodisc instruction demonstrated sufficient utility in terms of effectiveness, cost, and acceptance to recommend that it now be routinely considered and used in Defense training and education.

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A. PURPOSE

The 1989 Department of Defense Appropriations Bill directed the Department of Defense (DoD) 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. Accordingly, a quantitative, analytic review--a "me[illegible]s"--of what has been learned about the effectiveness and cost of interactive vide[illegible]uction was completed and is reported here.

B. METHOD

Empirical evaluation studies comparing interactive videodisc instruction with conventional instruction were collected from three instructional settings: military training, industrial training, and higher education. Results from these studies were then calculated using effect size, which is widely used in meta-analytic reviews and which provided a common, quantitative measure of instructional effectiveness that could be applied across all studies considered. Effect size is a standardized index, measured in standard deviations, of the difference--in this case the difference in instructional achievement--between two treatment groups. It is discussed further in the body of the paper. In this review, the larger the effect size, the more effective interactive videodisc instruction was found to be than conventional instruction.

C. FINDINGS

The findings of this review principally concern the instructional capabilities, or functionalities, made available by interactive videodisc systems, not the hardware itself.

1. Effectiveness

Interactive videodisc instruction was used successfully to teach. Four comparisons of interactive videodisc instruction with a "placebo" treatment in which no relevant instruction was given, resulted in an average increase in achievement of 1.39 standard deviations, or, roughly, an increase in the achievement for 50th percentile students to about the 92nd percentile of achievement.

Overall, interactive videodisc instruction was more effective than conventional instruction. Forty-seven comparisons of interactive videodisc instruction with conventional approaches were identified for this review. Over all instructional settings (military training, industrial training, higher education), instructional approaches (simulation only, tutorial only, simulation and tutorial combined), and outcomes (knowledge, performance, retention), interactive videodisc instruction increased achievement an average of 0.50 standard deviations over conventional instruction (an increase for 50th percentile students to about the 69th percentile of achievement).

Interactive videodisc instruction was more effective than conventional instruction in military training. Twenty-four comparisons of interactive videodisc instruction with conventional approaches to military maintenance, operator, and command training were identified for this review. Over all instructional approaches and outcomes, they showed an average increase in achievement of 0.38 standard deviations (an increase for 50th percentile students to about the 65th percentile of achievement).

Interactive videodisc instruction was more effective than conventional instruction in higher education. Fourteen comparisons of interactive videodisc instruction with conventional approaches to instruction in higher education settings (colleges and universities) were identified for this review. Over all instructional approaches and outcomes, they showed an average increase in achievement calculated using pooled standard deviations of 0.69 standard deviations (an increase for 50th percentile students to about the 75th percentile of achievement). The lower average effect sizes found for military training than for higher education may be due to a focus in military training on reaching threshold level(s) of achievement with minimized costs and time so that students who reach achievement criteria are sent on to duty assignments rather than held in the instructional setting as they are in higher education.

Interactive videodisc instruction was equally effective for both knowledge and performance outcomes. The average effect sizes calculated using pooled standard deviations for 27 knowledge outcomes (facts, concepts, and other information students acquired) and for 20 performance outcomes (procedures, skills, and other capabilities students could demonstrate) both averaged around 0.35 standard deviations (suggesting an improvement of 50th percentile students to about the 64th percentile).

The more the interactive features of interactive videodisc technology were used, the more effective the resulting instruction. One study examined this issue directly and found greater achievement with greater levels of interactivity. The issue can also be examined by comparing the effect sizes for Level II videodisc instruction (–.70, overall) with those for Level III videodisc instruction (.50, overall).

Directed, tutorial approaches were more effective than stand-alone simulations in interactive videodisc instruction. Effect sizes averaged 0.70 for tutorial approaches, 0.40 for combined tutorial and simulation approaches, and 0.15 for simulations by themselves.

Within-group variability was smaller in interactive videodisc instruction than in conventional instruction. In nearly every comparison of interactive videodisc instruction with conventional instruction, achievement in the interactive videodisc instruction group was less variable than in the conventional instruction group, suggesting there was more equitable distribution of achievement using interactive videodisc instruction.

Interactive videodisc instruction was more effective than computer-based instruction without videodisc interaction. Both interactive videodisc instruction and computer-based instruction have been found to be more effective than conventional instruction. However, the average effect size of around 0.69 observed for interactive videodisc instruction used in colleges is considerably higher than both the average effect size of 0.26 found in a review of computer based instruction used in colleges and the average effect size of 0.42 found in a review of computer-based instruction used in adult education.

There was little in the reviewed studies to indicate how interactive videodisc instruction achieves its success. The studies examined in this review did little to indicate which features of interactive videodisc instruction contribute to the observed increases in student achievement. Additionally, there are many outcomes--such as speed of response, accuracy of response, attitude toward the subject matter, insight, transfer, and retention--that may alone or in some combination become the objective(s) of instruction. How different designs for interactive videodisc instruction contribute to accomplishing these different outcomes was rarely addressed by the reviewed studies and remains a proper topic for future research.

2. Cost

Interactive videodisc instruction was less costly than conventional instruction. All 13 cost ratios (the ratio of costs for interactive videodisc instruction over costs for conventional instruction) found for this review were less than 1.0, indicating lower costs in every measured instance for interactive videodisc instruction. The average across all 13 cost ratios was 0.36. The average amount of student time saved across the studies covered by this review was 31 percent suggesting another source of savings from use of interactive videodisc instruction. Reductions in total military manpower that can result from such time savings in training may be an additional, significant source of cost savings, but this possibility was not examined here.

3. Cost-Effectiveness

Interactive videodisc instruction was more cost-effective than conventional instruction. Interactive videodisc instruction was found to be both less costly in all studies that reported costs and more effective overall than the conventional approaches with which it was compared. This finding should be viewed as suggestive rather than conclusive since no studies were found that used systematic models to provide empirical data on both cost inputs and effectiveness outputs.

4. Time on Task

Interactive videodisc instruction may increase time on task. Only one study reported an observation relative to this point. This study reported a 45 percent increase in the time spent practicing a targeted task as a result of the introduction of interactive videodisc instruction. This result was viewed as promising, but not conclusive.

5. Retention

Interactive videodisc inst[illegible]ion seems unlikely to effect retention. Four studies addressed retention. Both negative and positive results moved closer to zero over the retention intervals considered in these studies. Post-training experiences typically influence retention of knowledge and performance in a powerful manner. Findings for interactive videodisc training corroborate other Defense experiences with new training approaches that suggest their value lies primarily in improving the efficiency of instruction, not in assuring longer retention.

D. CONCLUSION

The 47 studies reviewed here indicate that interactive videodisc instruction is both more effective and less costly than conventional instruction. They suggest, therefore, that interactive videodisc instruction can have a significant positive impact on the productivity of resources allocated to military training and education and on the availability of people needed to operate and maintain military systems. Although more needs to be learned about how interactive videodisc instruction should be designed and employed, it should now be routinely considered and used in military training and education.

I. INTRODUCTION

A. PURPOSE

The 1989 Department of Defense Appropriations Bill directed the Department of Defense (DoD) 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.

DoD has been a leader in the development of interactive videodisc technology and has completed many evaluative studies 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 of interactive videodisc applications in military training, industrial training, and higher education was undertaken and completed in response to the Congressional direction.

B. BACKGROUND

1. Military Training

Military training in the United States is a substantial enterprise. Some notion of the extent and scope of this activity is provided each year by the publication of the Military Manpower Training Report. This report describes how the trained manpower needs projected by another annual report, the Manpower Requirements Report, are to be provided in the coming fiscal year.

The Fiscal Year 1990 *Military Manpower Training Report* (MMTR, 1989) reports that on an average day in FY 90 about 208,000 active duty personnel and 47,000 National Guardsmen and Reservists will undergo some form of formal training. This training load increased by about 8 percent in the 1980-1990 period. The cost of this effort will exceed $18.3 billion in FY 90, and it will require the support of about 176,000 military and civilian personnel to provide instruction, administration, and student supervision.

However, the MMTR understates the magnitude of the total military training enterprise. It only concerns instruction conducted in formal courses by organizations whose primary mission is education or training. It excludes job-site training, factory and unit training for new systems, organized team training for performance of specific military missions, and all field exercises. The magnitude of resources allocated to these latter activities is difficult to determine, but it is likely to exceed the MMTR dollar projections by a factor of two or three.

Military training is a complex as well as a sizable undertaking. At least six factors contribute to this complexity:

(1) The supply of people available for military service is decreasing. In the period 1978-1990, the number of people reaching age 18 each year dropped from about 4,250,000 to about 3,150,000. At present the Services must recruit 50 percent of all male citizens who are not in college, not disqualified for mental, moral, or physical reasons, and are age 18-21; by 1995, this proportion could grow to 77 percent (Binkin, 1986). It will be particularly difficult to recruit people for high-skill military occupations since educational and/or second language difficulties will become increasingly common in the population of militarily eligible people.

(2) The number of military systems is increasing. At the end of World War I there were about 500 materiel systems fielded by the the U.S. military, at the end of World War II this number had increased to about 2,000, and currently there are about 4,000 systems either fielded or in planning. In the Army there are about 0.78 large systems per person--there is one wheeled vehicle for every four people, one tracked vehicle for every 20 people, one radio for every six people, one generator for every 10 people, and so on. If no technological changes were made in the complexity of military systems, their quantity and variety would by themselves substantially increase the demands on military training to provide the people needed to operate and maintain them.

(3) The technological complexity of military systems is increasing. In 1939, the volume of technical documentation required for the J-F Goose, "Catalina Flying Boat" was 525 pages of information. In 1962, the volume required by the A-6A Intruder was about 150,000 pages of information. In 1975, the volume required for the F-14 Tomcat was about 380,000 pages of information. In 1979, estimates for the B-1 bomber were in the neighborhood of 1,000,000 pages of information (Kline and Gunning, 1979). This trend will doubtless continue. Whether the complexity of military systems necessarily translates into increased job complexity is a topic of continuing debate. Nonetheless, the

demand for people prepared to hold jobs classified as technical or highly technical has increased. The Army projected the number of people required in jobs categorized as "Very Technical" and "Technical" to increase by about 6 percent from 1984-1990, and the Navy projected an increase of about 14 percent in "Highly Technical" and "Technical" categories over the same period (Binkin, 1986).

(4) Costs to conduct training in the field have risen in absolute terms and in terms relative to other DoD expenses. Fuel and ammunition have been major contributors to increased military training costs. Fuel costs will never return to pre-1970 levels, and ammunition costs continue to rise along with the sophistication of new military systems. Additionally, the ranges needed to exercise the long reach of the newest systems are scarce, expensive, environmentally controversial, and have increased training costs substantially.

(5) Modern warfare doctrine calls for more widely dispersed and more autonomous units. Access to training devices, subject matter expertise, qualified instructors, and training equipment will be substantially reduced by the need to maintain unit dispersion. Military trainers must increase their capacities for delivering training to dispersed and isolated job-sites--they must deliver training to students rather than deliver students to training.

(6) 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.

Military trainers are aware of these challenges, and they have found that conventional approaches will not meet the new demands for increased training effectiveness without raising costs. Accordingly, they have sought new instructional approaches for meeting these new requirements. It is not surprising to find them turning to our most powerful new technologies for these approaches. Interactive videodisc technology is prominent among the new instructional approaches being tried.

2. Videodisc Technology

Like computer-based instruction, interactive videodisc instruction requires students to participate actively in the training environment, it provides practice with high quality simulation of devices that cannot be made available for training, and it distributes and standardizes both the content and interactions of high quality training to widely dispersed sites. Unlike computer-based instruction, interactive videodisc instruction also provides rapid, random access to a large, inexpensively stored data base of video quality images and sequences.

Interactive videodisc technology links videodiscs and videodisc players with computers. Generally, the videodisc serves as a storage medium for 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 power and functionalities added by videodisc technology give it an identity of its own.

Videodisc technology uses metalized plastic discs to code information as tiny pits (about 0.5 microns in diameter) 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 may cost less than $20 depending on quantity. DoD has specified a standard format, LaserVision, for production of all the videodiscs it uses.

Videodiscs are available in several sizes--the most common are 8 inches and 12 inches in diameter. The 12 inch interactive videodiscs 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 MB (megabytes) 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.

Levels of interactivity--or the ability to respond to the actions of users--have been identified for videodisc systems of different configurations. Supplying trainers with a videodisc system at one level or another does not guarantee that it will be used in a fashion commensurate with its potential. This potential may or may not be fully used depending on the imagination and capabilities of instructional developers. However, these levels do identify progressively higher ceilings for interactivity.

The following definitions of videodisc levels of interactivity were 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, which 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. The videodisc functions both as an optical storage device for digital information and as the source of analog picture and sound. The video frames on the videodisc store digital data intended to be read and processed by the computer.

Since the difference between Level III and Level IV depends on where and how digital information is stored--in Level III it is generally stored on a digital device, such as a magnetic disk, and in Level IV it is stored on videodisc--whether or not Level IV provides the potential for more interactivity than does Level III is a topic of continuing debate.

The five definitions are listed here for the record. Only two levels (II and III) were found among the evaluations identified for this review. The term "interactive videodisc" in contrast with "videodisc" alone implies the presence of a computer, and it is used here to refer to Level III presentations.

3. Interactive Videodisc Instruction

New optical technologies based on compact discs such as CD-ROM (compact disc-read only memory), CD-ROM/XA (CD-ROM Extended Audio), CD-I (compact disc-interactive), DVI (digital video-interactive), and others still emerging (e.g., UVC Corporation's approach to video compression), as well as new approaches for computer-generated imagery, will compete for the market currently held by videodisc systems. However, the instructional capabilities, or "functionalities," of interactive videodisc systems are the concern of this review. Regardless of the hardware system eventually chosen to deliver them, the functionalities made available by interactive videodisc technology are likely to be preserved and pursued by the training community for the foreseeable future.

These functionalities include those seen in computer-based instruction. Drill and practice, tutorials, simulation, and gaming may all be enhanced by the ability of videodiscs to store on one randomly accessible medium substantial amounts of information in many different formats such as video still images, motion video, analog audio (on separate and different tracks), and digital information such as compressed audio, curriculum data bases, and computer programming.

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

- **Surrogate travel**. This capability simulates a path of travel selected by the user over terrain representations stored on videodisc. Areas chosen to demonstrate this capability have included a small city, a harbor, a nuclear power plant, and an art gallery. Using surrogate travel, the user chooses the path, controls the speed of advance, and directs 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. The videodisc frames that 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.

- **Interactive movies.** One problem with training that requires demonstrations of skilled performance is that essential components of the demonstrations may be 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). Interactive movies are prepared by storing many different views of skilled performance on videodisc and making them available in parallel under the viewer's control.

- **Microtravel.** This capability combines surrogate travel with interactive movies and allows travel in places where people cannot go. One demonstration of this capability for Defense training provided microtravel through a jeep engine while it was running.

- **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. The data may be in almost any form, and the spatial data management systems developed by DoD provided the earliest implementations and demonstrations of this approach to hypermedia presentations.

- **Low-cost portable simulators.** One of the first military skill training videodiscs, developed in the late 1970s, was an Army tank gunnery trainer. This interactive videodisc simulation uses motion video segments stored on videodisc to provide tactical environments 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. As can be seen from the evaluations discussed in this report, many other simulations were subsequently developed for military training.

In Defense as elsewhere, training is a major application for interactive videodisc technology. About half of the approximately 100,000 videodisc systems in non-consumer use during the mid-1980s in the United States were used for training (Miller, 1987). The effectiveness of these applications is of substantial and natural interest both inside and outside DoD. Many organizations want to know what their investment in interactive videodisc instruction has bought in terms of increased instructional effectiveness. That is the principal topic of the review reported here.

II. APPROACH

This review is limited to an instructional medium--interactive videodisc. Therefore one criterion for including studies in this review was the use of a videodisc hardware system. The unambiguity of this criterion clarifies what studies were candidates for inclusion in this review, it aids replication, and it helps readers judge for themselves the relevance of this work to their own needs.

On the other hand, the approach is subject to the cautions raised by many commentators and best articulated by Clark's (1983) critique of research on the instructional effectiveness of media. These concerns may be summed up by the notion that hardware alone does not define an instructional approach--what is done with the hardware is what counts. This point of view seems unequivocal. The presence of a computer controlled videodisc system is no guarantee of effective instruction nor even that the unique features of the system will be used.

Critics of media effectiveness research push the argument farther. Clark states that "The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition" (page 445). This statement may go too far. Improvements in the technology of delivering food from centers of production to markets has had a tremendous impact on the nutrition of nations. The technologies by themselves do not guarantee this impact, but the functionalities they support and their applications do. The development of movable type did not by itself have an impact on learning, but the functionalities it supported and their application to instruction did--no books, no mass education.

This argument may extend to any medium, interactive videodisc included. The functionalities made possible and affordable by interactive videodisc technology hold substantial promise for instruction. Experimental investigation of these functionalities is essential to their effective application, and work concerning interactive videodisc functionalities such as that being done by Hannafin and his associates (e.g., Hannafin, 1985; Phillips, Hannafin, and Tripp, 1988) and others (e.g., Gay, 1986) --even when it employs videotape rather than videodisc (e.g., Levenson, Morrow, and Signer, 1985; Tiene, Evans, and Milheim, 1988)--is needed, commendable, and to be encouraged, as

Clark's article suggests. This review, however, is more summative. It is intended to bring together what we have learned thus far about the effectiveness of interactive videodisc technology applied to instruction.

The following criteria guided the choice of studies for this review.

(1) The studies had to conform to standard criteria for care and control in the conduct of evaluation research. These criteria are generally accepted and discussed in research literature concerning methodology for the design and conduct of experiments in the social and behavioral sciences.

(2) The studies had to involve a comparison of an instructional approach using interactive videodisc with conventional instruction. "Conventional instruction" was assumed to involve all of the non-or limited-interaction approaches now available to instructors including platform lecture, text, programmed text, on the job training, experience with actual equipment, and even video and videotape instruction. It excluded highly interactive approaches such as computer-based instruction or interactive videodisc instruction.

This requirement meant that the choice of studies was limited to comparisons of experimental and control group performance. It is possible, and perhaps desirable, to evaluate an instructional approach without these comparisons. For instance, tracing a "trajectory" of student progress through a course as described and applied by Suppes, Fletcher, and Zanotti (1976) directly relates time in instruction to achievement and is more powerful than the experimental group/control group comparisons sought here. However, comparisons were needed to calculate effect size, and studies without them were excluded. Some studies that only examined the effectiveness of different approaches to the design of videodisc instruction were excluded. Those that compared different levels of interactivity were included in this review, but others of this sort were not.

(3) The studies had to involve computer-controlled--Level III--videodiscs. Four studies were found that involved Level II videodiscs. These are reported and discussed briefly, but their results are not aggregated with the descriptive statistics reported for Level III studies. Some good experimental studies turned up (e.g., Levenson, Morrow, and Signer, 1985) that used videotape players to mimic the interactive capabilities of instruction using videodisc

players. However, they did not use videodiscs, and they were not included among the studies reviewed here.

(4) The studies had to report sufficient data to permit calculation of effect size. Generally, means and standard deviations were needed for all treatment groups. In the absence of these data it was occasionally possible to estimate effect size from other information provided--especially information obtained from significance tests. Glass, McGaw, and Smith (1981) describe a number of ways to calculate effect size when means and standard deviations are not provided directly. These methods were used when they could be.

(5) The studies had to concern military training or use students of about the same age and type as military training students. In practice, this meant that the studies were limited to military training, higher education, and industrial training. Only one study using non-handicapped elementary school students (Hasselbring et al., 1988) and only two using non-handicapped secondary school students (Blatnik and Holden, 1988; Gale and Barksdale, 1989) turned up.

(6) All work with handicapped students was excluded. Research on videodisc applications for handicapped students has a long and vigorous history. Work by Hofmeister (e.g., Hofmeister, Engelmann, and Carnine, 1986), Thorkildsen (e.g., 1985), Browning (e.g., Browning et al., 1986), and their colleagues is notable. A review of this work could probably be supported by the state of the art, but it is beyond the scope of this investigation.

This investigation benefited from other reviews of interactive videodisc instruction. These reviews include those by Bosco (1986), DeBloois, Maki, and Hall (1984), DeBloois (1988), an annotated bibliography compiled by Sarli et al. (1988), and a review completed by Capper (in press). On the basis of these reviews, it was evident that the state of our knowledge would support a quantitatively oriented, analytic review of the effectiveness of interactive videodisc instruction.

A. TECHNICAL APPROACH

The methodology used for analytic reviews has changed considerably in the last 15 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 is 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--low ability to detect statistically significant differences between two groups--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; and (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 still developing as a technique and some matters concerning its use remain unsettled. The issues receiving the most attention at present concern the "file-drawer problem" and the calculation of effect size. The use of meta-analysis to perform research syntheses that include costs (syntheses involving cost-effectiveness) remains unaddressed and undetermined.

The file-drawer problem may stem from the reluctance of professional journal editors to include studies whose results fail to reach statistical significance and the reluctance of researchers to report their null results--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)--among others--seems to be not much. Nonetheless, steps were taken in this review to locate studies left in file-drawers.

Effect size is usually defined as the difference between the means of two groups divided by the standard deviation of the control group. Effect sizes calculated in this way estimate the difference between two group means measured in control group standard deviations. Glass et al. (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.

Alternatively, Hedges and Olkin (1985) show that, for every effect size, both the bias and variance of its estimate are smaller when the standard deviation is obtained by pooling the sample variance of two groups instead of using the control group standard deviation by itself. An effect size based on a pooled standard deviation estimates the difference between two group means measured in standard deviations estimated for the full population from which both experimental and control groups are drawn. Both approaches are used in this review to estimate effect sizes and both are reported whenever sufficient data were available to calculate them.

If the standard deviations for both control and experimental groups are about the same in magnitude, effect sizes calculated using control group standard deviations will differ little from those calculated using pooled standard deviations. If, on the other hand, effect sizes are larger when they are calculated using pooled standard deviations than they are when they are calculated using control group standard deviations, there must necessarily be smaller standard deviations and less variability across the measure of interest in the experimental group than in the control group. This is the case found here. The effect sizes calculated in this review using pooled standard deviations were generally larger than those calculated using control group standard deviations.

Most commentators suggest that effect sizes can be treated as descriptive statistics and entered into standard tests for statistical significance. Hedges and Olkin (1985) have shown that the error variance around estimates of effect size is inversely proportional to the sample size of the studies from which the effect sizes are drawn. If the effect sizes in any review are drawn from studies employing widely different sample sizes, then the heterogeneity of variance among effect sizes prohibits their use in conventional t-tests, analyses of variance, etc. In this review the sample sizes vary by a factor of 20; hence the effect sizes reported here are treated only with descriptive statistics. Standard deviations and sample sizes for effect sizes are reported so that others may examine the results further using such inferential means as they wish.

B. DATA COLLECTION

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, the following terms were used by themselves:

- Interactive Videodisc
- Interactive Video
- Interactive Courseware.

This search turned up more than 2,400 candidate studies. Most of these studies concerned computer-based instruction alone and not interactive videodisc instruction. This search was not without value, since it identified about two-thirds of the studies eventually used in this review. On the other hand, there were several studies that were known to exist but that did not turn up in this search. Some of these studies are unpublished and not catalogued anywhere. Others are published but not catalogued using any of the above keywords. Still others exist only as laboratory reports. Whatever the case, it was necessary to decide whether or not to include studies that did not turn up in the formal search process. A decision was made to include them.

To locate uncatalogued, unpublished evaluation studies, we[1] 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. We pursued this by publishing a notice in the *Videodisc Monitor*, by calling every developer listed in the 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 not formally

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[1] I was assisted in this process by Dr. Ruth Wienclaw, to whom I am grateful.

published. Few such documents emerged. We were gratified by the willingness of researchers to root through their personal files 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 telephoned a number of researchers directly to obtain original data to permit calculation of effect sizes when the necessary data were missing from their report documentation. As usual we encountered helpful, faciiitating people who were willing to dig through their personal files and send us whatever they felt would be relevant.

III. FINDINGS AND DISCUSSION

A. TABULATION OF STUDIES

The effectiveness of interactive videodisc applications in training and education can be assessed by examining the effect sizes reported in Appendix A. That appendix is intended to invite exploration of data collected for this review and (re)examination of the findings presented in this paper.

Outside of what could be determined by descriptions of the instructional approach and what could be determined from the evaluation results, direct assessment of interactive videodisc content or quality was beyond the scope and resources of this investigation. Aspects such as the quality of graphics, clarity of instructional text, and verisimilitude of simulations were not assessed. The state of the art in interactive videodisc instruction could most probably support such an analysis, and it would be an appropriate next step, but it was not attempted here.

There are 28 studies summarized in Appendix A--some with more than one reference. The Appendix is organized so that the 13 military training studies are listed first, the 4 industrial training studies are listed next, and the 11 higher education studies are listed last. Within these groups, the studies are listed chronologically. Two studies were performed at the US Air Force Academy (Crotty, 1984; Verano, 1987). Although these studies used military subjects (cadets), their setting seemed more characteristic of higher education than military training, and they are included with the higher education studies.

Although 9 of the 17 studies in military and industrial training settings concerned electronic maintenance, instructional content concerned a variety of subject matter, including "softer" topics such as military operations in urban terrain (King and Reeves, 1985), interpersonal skills (Schroeder et al., 1986), and handling of hazardous materials (Bosco and Wagner, 1988). None of the 11 studies in higher education settings concerned electronics maintenance. Their instructional content ranged from equipment operation (Fowler, 1980), CPR instruction (Lyness, 1987), and medical education (Allan, 1989) through biology (Bunderson, et al., 1984, Davis 1985), physics (Stevens, 1984), and chemistry (Smith et al., 1986; Jones, 1987; Jones 1988), to foreign language instruction (Crotty, 1984; Verano, 1987).

The main distinction in instructional approaches was among those applications that used the videodisc as a tutorial, programmed textbook with visuals--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. Judgments concerning instructional approach were based on documentation of the instruction and on discussions with developers or others who had direct experience with it.

In Table A-1 (Appendix A), the "N" column lists the number of subjects in the experimental (Exp) and the control (Ctrl) groups.

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 were compared with each other or computer assisted instruction (CAI) was compared with the control treatment. Findings from these comparisons are also included in Appendix A. One paradigm that is listed frequently in the Comparison column involves instruction using videodisc-based simulations of equipment compared with instruction using hands-on experience with the actual equipment (AE) that was the object of the instruction.

As shown in the Outcome column, four categories of effectiveness data for interactive videodisc instruction were identified. These categories were: knowledge outcomes, which assessed students' knowledge of facts and/or concepts presented by the instruction; performance outcomes, which assessed students' skill in performing some criterion tasks or procedures; retention, which reported knowledge or performance measures taken some time after instruction ceased; and time to complete the instruction. It was assumed that time to complete a performance test was properly considered as a performance outcome measure, but that time to complete the instruction itself should be considered separately.

Effect size (ES) was calculated as the difference in the group means divided both by the pooled standard deviation (Comb SD) and, where possible, by the control group standard deviation (Ctrl SD). In some cases, effect size was estimated from other statistics using procedures suggested by Glass et al. (1981).

Some studies involved simultaneous comparison of more than two treatment groups and began with an analysis of variance (ANOVA) before comparing 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. Each 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 is 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 ($p \geq .05$). Otherwise, the significance level reported in the study is listed.

Superscripts are used in the "ES Comb SD" (Effect Sizes Based on Combined or Pooled Standard Deviations) column to indicate the categories into which the effect size was coded. Effect sizes based on knowledge outcomes are signified by a superscript "K", and those based on performance outcomes are signified by a superscript "P". Effect sizes based on time to complete the instruction are signified with a superscript "D" (duration). Only 8 studies in Appendix A reported time to complete instruction, so knowledge and performance outcomes were combined and coded together for these duration outcomes. Effect sizes based on retention are signified with a superscript "R". Only four studies in Appendix A measured retention, so knowledge and performance outcomes were also combined and coded together for retention outcomes.

Superscripts are also used in "ES Comb SD" column to indicate how the effect sizes were coded with respect to instructional approach. Effect sizes judged to be based on tutorial approaches without simulation are signified by a superscript "T", those judged to be based on tutorial approaches combined with simulation are signified by a superscript "C", and those judged to be based on simulation alone are signified by a superscript "S".

Four studies reported "Baseline" comparisons of interactive videodisc instruction with control conditions in which no instruction or irrelevant placebo instruction was provided. Generally, these studies tell us if interactive videodisc instruction teaches anything. Effect sizes concerning these baseline comparisons are signified with a superscript "B" in the appendix.

Some studies used interactive videodisc instruction in both comparison groups but compared high or more extensive interactivity with low or less extensive interactivity.

Effect sizes based on these comparisons of level of interactivity are signified with a superscript "I".

Some of the effect sizes reported in Appendix A are included for general interest and completeness but were not used in this review. Among these are effect sizes based on comparisons that did not involve videodisc instruction at all. For instance, one of the post-ANOVA pairwise comparisons reported by Gibbons et al. (1983) concerned computer-assisted instruction (CAI) and classroom instruction, and its effect size was not considered further in this review. Also reported but excluded from further consideration were effect sizes involving interactive videodisc instruction in the experimental group, but an interactive approach in the control group not ordinarily viewed as conventional instruction. For instance, another post-ANOVA comparison reported by Gibbons et al. involved computer-assisted instruction in the control group. Another example is Fowler's (1980) comparison of linear interactive videodisc instruction with branched videotape instruction. Finally excluded from further consideration were effect sizes involving interactive videodisc instruction in which the use of the videodisc capability was constrained--usually for good experimental reasons. For instance, Verano (1987) included comparisons using videodisc instruction constrained to strictly linear presentations.

The signs of values reported in the Percent Improvement column were determined in a manner similar to that used for the Effect Size column. Each percent 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, costs were not reported in these studies, although many authors acknowledged cost and cost-effectiveness to be significant issues. The abbreviation "na" is used in the Cost Ratio column to signify that the data of interest were not reported and not available.

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 Appendix A are based on initial investment (II), operating and support (OS) costs, or both combined.

An assumption made in aggregating effect sizes is that each effect size is obtained independently of the others and that it independently estimates the true effect size.

However, several investigations listed in Appendix A measured more than one instructional outcome for the same experimental condition and for the same experimental subjects. These outcomes are non-independent, correlated estimators of true effect size and should not be treated as if they were independent. Hedges and Olkin (1985) present methods of estimating a common effect size from a vector of correlated estimators. Unfortunately, the correlations needed to apply their methods are rarely reported. Further, as Hedges and Olkin point out, the gain in efficiency resulting from using their multivariate methods seldom justifies the required effort. An alternative approach is simply to average non-independent effect sizes across a single experiment, and that is the approach used here.

In calculating these averages, it was necessary to decide what were separate experimental comparisons, independent and worthy of separate entry, and what were not. When more than one result was reported and more than one effect size was calculated from the same investigation, the following assumptions guided these decisions:

(1) If the effect sizes were based on comparisons using different students/subjects, it was assumed they constituted different experiments and the effect sizes were not averaged.

(2) If the effect sizes were based on comparisons involving different (more than one) experimental groups with the same control group, it was assumed they were different measures of different experimental conditions and the effect sizes were not averaged.

(3) If the effect sizes were based on comparisons involving the same experimental treatment (one experimental group) but different (more than one) control groups, it was assumed they were different measures of the same experimental conditions and the effect sizes were averaged.

(4) Different experiments using the same interactive videodisc instruction materials were not averaged.

In Appendix A, a superscript "X" in the "ES Comb SD" column signifies an average effect size calculated for two or more measures reported for the investigation--"KX" signifies an average calculated for knowledge outcomes, "PX" signifies an average calculated for performance outcomes. "AX" signifies an overall average calculated for knowledge, performance, retention, and/or duration (time to complete the instruction) outcomes.

B. EFFECTIVENESS

1. Principal Outcomes

Effect sizes for the four principal measures of merit--knowledge outcomes, performance outcomes, retention of knowledge or performance, and time to complete the instruction--were averaged across all 28 studies and are shown in Table 1. The effect sizes reported here and elsewhere are organized into three columns:

- Column one shows the average effect size for all available studies for the row category. The effect sizes entered into this average are all based on effect sizes calculated from pooled standard deviations.
- Column two also shows average effect sizes calculated from pooled standard deviations. However, they are based only on those studies that presented sufficient data to allow both pooled and control group standard deviations to be used in calculating effect size.
- Column three shows average effect sizes calculated using control group standard deviations only.

All the effect size averages in Table 1 that were calculated using pooled standard deviations are larger than those calculated using control group standard deviations. This is a stable finding in this review. It indicates that control group standard deviations were generally larger than experimental group standard deviations and that interactive videodisc instruction raised average achievement more equitably across all students than did conventional instruction. The increases in achievement under interactive videodisc instruction were not due to a few students who were permitted to surge ahead in achievement (and increase the variance). This result is especially important for training where a principal concern is to raise as many students as possible across a threshold--or thresholds--of achievement rather than simply to maximize average achievement, which is accomplished most efficiently by concentrating instructional resources on the best students.

The bottom section of Table 1 shows overall average effect sizes aggregated across all studies and all four measures of merit. The number of measures that contributed to the overall effect sizes reported in the table is less than the sum of measures contributing to the other effect sizes since some within-study measures of merit for a single experimental condition were averaged together. These within-study averages, which were used to calculate the overall average effect sizes reported in Table 1, are shown in Appendix A and signified with an "X" as discussed above.

Table 1. Average Effect Sizes for Knowledge Outcomes, Performance Outcomes, Retention, and Instruction Completion Time

	ES Based on Pooled SD	ES Based on Pooled SD When Ctrl SD Also Available	ES Based on Ctrl SD
Knowledge Outcomes			
Mean	0.361	0.375	0.361
SD	(0.493)	(0.506)	(0.533)
N	(27)	(23)	(23)
Performance Outcomes			
Mean	0.349	0.398	0.334
SD	(0.556)	(0.569)	(0.447)
N	(20)	(15)	(15)
Retention			
Mean	0.547	0.750	0.650
SD	(0.511)	(0.523)	(0.339)
N	(3)	(2)	(2)
Time to Complete Instruction			
Mean	1.178	1.267	1.185
SD	(0.382)	(0.474)	(0.570)
N	(8)	(5)	(5)
Overall			
Mean	0.502	0.487	0.439
SD	(0.552)	(0.563)	(0.524)
N	(47)	(38)	(38)

Table 1 shows 47 knowledge, performance, retention, and time to complete measures averaged to provide an overall measure of merit for interactive videodisc instruction compared to conventional instruction. Of these, 38 were positive. The effect sizes ranged from −1.14 to 2.18. Their average is 0.50, and their median value is 0.26 for effect sizes based on pooled standard deviations and 0.28 for effect sizes based on control group standard deviations. Their average of 0.50 is 20-80 percent larger than effect sizes found in meta-analyses of computer-based instruction--such as those summarized by 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. A mean effect size of 0.50 from a sample as large as 47 suggests that through the use of interactive videodisc technology, a trainer can expect to increase the achievement of students by about one-half a standard deviation above their present level of achievement. Or, assuming a normal or Gaussian distribution, the average graduate, the graduate at the 50th percentile, would improve to the level of graduates currently at the 69th percentile through the use of interactive videodisc technology. Military training is more concerned with numbers of students who reach defined thresholds of knowledge or performance per constant expenditure, than with increases in their achievement. In less normative terms then, and assuming a linear rate of learning, an effect size of 0.50 suggests, roughly, an improvement of 19 percent in number of graduates through the application of interactive videodisc instruction.

Performance and knowledge outcomes are reported separately in Table 1. These results show that the average effect sizes for these two achievement measures are similar, and suggest that there is little reason to expect interactive videodisc instruction to be any more effective for performance outcomes than for knowledge outcomes, although in both cases it is more effective than conventional instruction. The average effect sizes for performance outcomes range from 0.334 for 15 studies based on control group standard deviations to 0.398 for the same studies based on pooled standard deviations. The average effect sizes for knowledge outcomes range from 0.361 for 23 studies based on control group standard deviations to 0.375 for the same studies based on pooled standard deviations. These results are generally the same for both knowledge and performance outcomes. They suggest an improvement of 50th percentile students to about 64th percentile achievement or an increase of about 14 percent in the number of students reaching criterion achievement levels.

Average effect sizes for time to complete instruction--or to reach criterion level(s) of achievement--are also shown in Table 1. These averages range from 1.178 for 8 effect sizes calculated across all available studies to 1.267 for 5 effect sizes based on pooled standard deviations. These results suggest an improvement of 50th percentile students to about the 88th percentile achievement, or an increase of 38 percent in the number of students reaching criterion achievement levels if time were held constant. Student time savings of about 30 percent have been noted in analyses of computer based instruction starting with a widely noted Orlansky and String (1977) study and continuing on into the present. The average percent time saved across the 8 studies in this review that reported time savings was 31 percent. Eight studies do not provide a conclusive base, but these results suggest that instruction time savings for interactive videodisc instruction are about the same as those for computer-based instruction.

One might well ask to what degree these time savings were due to self-pacing, to what degree they were due to self-pacing uniquely made possible by interactive videodisc instruction, and to what degree self-pacing was encouraged in the conventional instruction with which the videodisc instruction in these studies was compared. These questions were not well addressed by the studies summarized in this review. Generally the treatments were designed to allow the same flexibilities for completing conventional instruction as for interactive videodisc instruction, and results from these studies must stand until more focused research is performed and reported.

2. Instructional Settings

Overall average effect sizes for all four measures of merit were broken out of Table 1 and calculated separately for military, industrial, and higher education settings. They are shown in Table 2. The average effect size for military applications ranges from 0.385, based on 20 studies calculated using control group standard deviations to 0.416 based on the same experimental comparisons but calculated using pooled standard deviations. These results suggest an improvement of 50th percentile students to about 65th percentile achievement or an increase of 15 percent in the number of students reaching criterion achievement, assuming linear learning. With over 250,000 students involved in residential, formal instruction programs each day, these findings promise significant improvements for Defense training provided that the operations of schools are changed to take advantage of these improvements.

The average effect sizes for interactive videodisc instruction used in higher education are considerably greater than those for military training. In Table 2, they range from 0.660 for 12 studies based on control group standard deviations to 0.725 based on the same experimental comparisons but calculated using pooled standard deviations. These

Table 2. Average Effect Sizes for Military Training, Industrial Training, and Higher Education

	ES Based on Pooled SD	ES Based on Pooled SD When Ctrl SD Also Available	ES Based on Ctrl SD
Military Training			
Mean	0.391	0.416	0.385
SD	(0.543)	(0.543)	(0.451)
N	(24)	(20)	(20)
Industrial Training			
Mean	0.510	0.249	0.174
SD	(0.744)	(0.799)	(0.838)
N	(9)	(6)	(6)
Higher Education			
Mean	0.689	0.725	0.660
SD	(0.395)	(0.408)	(0.393)
N	(14)	(12)	(12)
All Settings Combined			
Mean	0.502	0.487	0.439
SD	(0.552)	(0.563)	(0.524)
N	(47)	(38)	(38)

results suggest an improvement of 50th percentile students to about 75th percentile achievement or an increase of 25 percent in the number of students reaching criterion achievement. Since the emphasis in training is properly on reducing costs to reach threshold levels of achievement, this emphasis may actually be observed in practice. The lower effect sizes found for military training may be due to this observance--students in training who reach threshold criteria are sent on to new assignments, whereas students in education are encouraged to continue improving. If this argument holds, we should expect to find effect sizes for industrial training that are closer to those of military training than to those of higher education.

Unfortunately, the findings for industrial training are less stable than those for either military training or higher education. In Table 2, they range from 0.174 for 6 studies based on control group standard deviations to 0.510 for 9 studies based on pooled standard deviations. The improvement of 50th percentile students suggested by these results ranges from 57th to 69th percentile achievement or an increase in the number of students reaching criterion achievement levels of 7-19 percent. The three additional studies that are included in the effect size average shown in Column 1, are all based on time to complete training. The remaining 6 studies, upon which the Column 2 and Column 3 effect size averages are based, are either knowledge or performance outcomes measured when the students completed the instruction.

The pattern of knowledge and performance measures across all three instructional settings is therefore of interest and is reported in Table 3. As this table suggests, the effect sizes from industrial training appear much closer to those of military training than to those of higher education if we limit consideration, as Table 3 does, to measures of performance and knowledge taken at the end of instruction.

3. Instructional Approaches

Another exploration concerned the influence of instructional approach--how the videodisc system was used--on instructional outcomes. The studies were categorized into three groups based on their instructional approach: studies in which the instructional approach was directive and tutorial; studies in which the instructional approach was based on freely explored simulations; and studies in which tutorial and simulation approaches were combined. These studies were crossed with those in which the instructional outcome assessed was knowledge or performance, which yielded the four (tutorial, combined, simulation, all three) by three (knowledge, performance, combined knowledge and performance) set of results shown in Table 4. Not surprisingly, there are too few studies in some of these categories. For instance, there was only one study in which a tutorial approach was used to produce a performance outcome. It should be emphasized that the categorization of instructional approaches in this review was generally based on evaluation documentation and not on direct experience with the instructional materials themselves.

Table 3. Average Effect Sizes for Combined Knowledge and Performance Outcomes in Military Training, Industrial Training, and Higher Education

	ES Based on Pooled SD	ES Based on Pooled SD When Ctrl SD Also Available	ES Based on Ctrl SD
Military Training			
Mean	0.353	0.380	0.357
SD	(0.541)	(0.533)	(0.446)
N	(23)	(19)	(19)
Industrial Training			
Mean	0.249	0.249	0.174
SD	(0.744)	(0.799)	(0.838)
N	(6)	(6)	(6)
Higher Education			
Mean	0.582	0.601	0.554
SD	(0.354)	(0.373)	(0.355)
N	(13)	(11)	(11)
All Settings Combined			
Mean	0.409	0.464	0.388
SD	(0.536)	(0.541)	(0.507)
N	(42)	(36)	(36)

There appear to be two main results from this analysis. First, there seems to be about the same amount of improvement in knowledge and performance outcomes for all approaches. There is some minor evidence here suggesting that simulation either alone or in combination with a tutorial yields stronger performance outcomes than knowledge outcomes. This finding seems intuitively reasonable, but it is too weak to do anything but suggest a line of follow-on investigation.

Second, there is an obvious increase in effectiveness across these studies from simulation-only approaches, which were least effective, through approaches combining simulation and tutorials, to tutorial approaches, which were most effective. Because of

Table 4. Average Effect Sizes for Tutorial Approaches and Instructional Outcomes

	Instructional Approach	Measure	ES Based on Pooled SD	ES Based on Pooled SD When Ctrl SD Also Available	ES Based on Ctrl SD
Knowledge Outcomes	Tutorial	Mean	0.703	0.703	0.660
		SD	(0.249)	(0.249)	(0.234)
		N	(6)	(6)	(6)
	Combined Tutorial & Simulation	Mean	0.398	0.360	0.385
		SD	(0.420)	(0.452)	(0.472)
		N	(12)	(10)	(10)
	Simulation	Mean	0.104	0.102	0.033
		SD	(0.536)	(0.604)	(0.629)
		N	(9)	(7)	(7)
	All Approaches	Mean	0.361	0.375	0.361
		SD	(0.493)	(0.506)	(0.533)
		N	(27)	(23)	(23)
Performance Outcomes	Tutorial	Mean	0.805	0.805	0.805
		SD	(na)	(na)	(na)
		N	(1)	(1)	(1)
	Combined Tutorial & Simulation	Mean	0.423	0.447	0.341
		SD	(0.692)	(0.746)	(0.554)
		N	(11)	(8)	(8)
	Simulation	Mean	0.191	0.265	0.250
		SD	(0.299)	(0.261)	(0.284)
		N	(8)	(6)	(6)
	All Approaches	Mean	0.349	0.398	0.334
		SD	(0.556)	(0.569)	(0.447)
		N	(20)	(15)	(15)
Combined Knowledge & Performance Outcomes	Tutorial	Mean	0.718	0.718	0.678
		SD	(0.230)	(0.230)	(0.219)
		N	(7)	(7)	(7)
	Combined Tutorial & Simulation	Mean	0.410	0.398	0.365
		SD	(0.553)	(0.583)	(0.495)
		N	(23)	(18)	(18)
	Simulation	Mean	0.145	0.177	0.133
		SD	(0.430)	(0.467)	(0.494)
		N	(17)	(13)	(13)
	All Approaches	Mean	0.409	0.464	0.388
		SD	(0.536)	(0.541)	(0.507)
		N	(47)	(38)	(38)

cost considerations, there is little here that argues against use of simulation. The cost arguments for simulation are very strong when a few thousand dollars of software and hardware can substitute for actual equipment or field experiences that may cost tens or hundreds of thousands of dollars. Results from this review show that such substitutions are both feasible and desirable. Cost arguments for tutorial approaches are seldom this strong since tutorials can usually be presented by relatively inexpensive means such as textbooks, programmed textbooks, or teaching assistants as well as by videodisc hardware. Moreover, simulation only approaches showed average effect sizes ranging from 0.033 (for knowledge outcomes) to 0.265 (for performance outcomes). They were, overall, more effective than conventional approaches. These results, combined with the favorable cost ratios that are generally found in simulation approaches, suggest that videodisc instruction using simulation alone may turn out to be the most cost-effective alternative even though it may be the least effective of the three approaches examined here.

The greater effect sizes observed for tutorial approaches over combined tutorial and simulation approaches are puzzling for at least two reasons. First, it seems intuitively reasonable that including simulation with a tutorial should add both value to the tutorial and effectiveness to the instruction. Just the opposite is suggested by these data. Second, the programmed instruction approach used in tutorial instruction is typically reported by reviews of paper-based (programmed textbook) approaches to produce substantially lower effect sizes than those found here. For instance, Kulik, Cohen, and Ebeling (1980) found that 57 studies of programmed instruction used in higher education to present a variety of subject areas improved performance by an average 0.24 standard deviations over conventional instruction, which is considerably less than the effect sizes for tutorial approaches reported in this review. The effectiveness of tutorial approaches used in interactive videodisc instruction evidently deserves further investigation.

The finding that directive, tutorial approaches yield greater instructional results than simulation approaches is supported by Gay (1986) who used a 2-by-2 experimental design and interactive videodisc instruction to investigate the effects of learner and program control on the achievement of students who had high and low prior knowledge of course content. Students in the learner control (non-tutorial) condition with low prior knowledge scored significantly lower in a post-test of course content than did students in the other three treatment groups. Gay's results along with those of this review suggest that directive, tutorial approaches may be best used when standardized results are to be obtained from students with a variety of prior knowledge, which is the typical case in military training.

On the other hand, high prior knowledge students in Gay's study who were in the learner control condition took significantly less time to complete the course and the post-test than did students in any of the other three treatment groups. This result may explain some of the mixed findings for directive, tutorial approaches found by this review, and it suggests that important efficiencies in training may result if the training approach can be adjusted for prior knowledge of course content.

4. Level of Interactivity

Average effect sizes from five within-videodisc comparisons (i.e., those that compare high levels of videodisc interactivity with lower ones) are shown in Table 5. These range from 0.456 for effect sizes based on control group standard deviations to 0.397 for effect sizes based on pooled standard deviations. The individual effect sizes that contribute to the averages reported in Table 5 range from a single negative effect size of –0.160 to 1.425. Since there are no absolute levels of interactivity--one study's high level of interactivity might be another study's low level of interactivity--it is difficult to interpret the magnitudes of these effect sizes directly. However, these studies suggest that the greater the level of interactivity, the greater the instructional achievement provided by the videodisc instruction.

Table 5. Average Effect Sizes for High Compared with Low Levels of Videodisc Interactivity

Measures	ES Based on Pooled SD	ES Based on Pooled SD When Ctrl SD Also Available	ES Based on Ctrl SD
Mean	0.397	0.397	0.456
SD	(0.533)	(0.533)	(0.631)
N	(5)	(5)	(5)

Notably, the Table 5 effect sizes based on pooled standard deviations are less than the effect sizes based on control group standard deviations. This result is contrary to almost all the previous effect size results. It means that the standard deviations across the five control groups were smaller than those of the experimental groups, and it suggests that when different levels of interactivity are compared within interactive videodisc approaches, greater interactivity is associated with greater instructional outcome variability. A result based on only five studies cannot be viewed as conclusive, but it does suggest a variable to be considered in future research.

Four studies of Level II videodisc instruction appeared in our search for empirical evaluations. These studies are summarized in Appendix B. As the Appendix shows, results from these evaluations are generally less positive than those reported for Level III applications. For that matter, five of the seven results that were statistically significant were negative, showing the videodisc application to be less effective than conventional instruction. Of course the lesser effectiveness of the videodisc instruction may be balanced out by lower cost. Unfortunately, none of these studies reported cost ratios, and the cost effectiveness of these applications remains unknown.

Table 8 summarizes the average effect sizes for Level II evaluations for knowledge, performance, and time to completion measures. Performance outcomes appear much lower than knowledge outcomes among these effect sizes, ranging from-1.752 and-1.565 for six performance outcomes to 0.385 and 0.350 for two knowledge outcomes. There are too few studies here to view this as a reliable result. Superiority of knowledge outcomes to performance outcomes from Level II videodisc presentations must remain for the present an interesting possibility.

The overall averages in Table 8 range from -1.031 for an average of 10 effect sizes based on control group standard deviations to-0.702 for 13 effect sizes based on pooled standard deviations. They are large enough to be considered seriously. Across the studies reported here, videodisc instruction based on Level II technology appears much less effective than conventional instruction.

The Table 6 average effect sizes based on pooled standard deviations are smaller in absolute magnitude than those based on control group standard deviations. This result suggests that there was generally less variation in the conventional instruction groups than in the Level II videodisc instruction groups. Since the videodisc instruction groups generally achieved lower scores on the outcome measures considered in the Level II studies, it may be that some students simply did not adapt to the videodisc presentations and found themselves unable to learn effectively from videodisc approaches--whereas other students progressed just as well using videodiscs as they would in conventional instruction. This possibility could be investigated by examining the raw data from these studies.

Table 6. Average Effect Sizes for Knowledge Outcomes, Performance Outcomes, and Instruction Completion Times for Instruction Using Level II Videodiscs

	ES Based on Pooled SD	ES Based on Pooled SD When Ctrl SD Also Available	ES Based on Ctrl SD
Knowledge Outcomes			
Mean	0.115	0.350	0.385
SD	(0.276)	(0.057)	(0.120)
N	(4)	(2)	(2)
Performance Outcomes			
Mean	-1.565	-1.565	-1.752
SD	(1.331)	(1.331)	(1.526)
N	(6)	(6)	(6)
Time to Complete Instruction			
Mean	-0.067	-0.245	-0.285
SD	(0.330)	(0.163)	(0.163)
N	(3)	(2)	(2)
Overall			
Mean	-0.702	-0.918	-1.031
SD	(-1.213)	(1.314)	(1.488)
N	(13)	(10)	(10)

The lower levels of interactivity provided by Level II videodisc systems may account for the lower levels of effectiveness found in these studies. Although this is not the only explanation, interactivity is one of the main differences between the studies summarized in Appendix B and those summarized in Appendix A. Notably, 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.

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 a Level II approach was used, the effect size was-0.17; when a Level III approach was used, the effect size was 0.29. This possibility is also supported by Verano (1987), who presented three levels of interactivity (linear, segmented, and interactive) to students. The higher the level of interactivity he used, the greater the students' achievement. Instructional evaluation generally requires a sizable body of research to achieve a conclusive result, but the combination of the Holmgren, Wankel, Stevens, and Verano results as well as the contrast between Level II and Level III effect sizes make a strong case for using the full capabilities of Level III videodisc media in instructional applications.

Extension of this conclusion to Level IV videodisc materials is probably not warranted. The step from Level III to Level IV, under the definitions used for this review, only marks a change in the way instructional materials are stored and not any improvement in the way they are presented. 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 (Fletcher, 1988).

5. Evaluation Issues

The above findings suggest favorable results for Level III interactive videodisc instruction relative to conventional instruction. They arise directly from available evaluation data on the effects of interactive videodisc applications in training and education. However, there are two issues to note concerning the studies from which these results are drawn:

(1) Most of the evaluations reported here were performed by developers who also produced the interactive videodisc instruction being evaluated. Few of the evaluations were performed by third parties. There are strengths and weaknesses in this approach. Developers are rarely indifferent to the success of their products and may, intentionally or not, bias the results of their evaluation. On the other hand, there are arguments that support initial evaluation of instructional materials by its developers and not by a third party

evaluator. For example, 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 summarized here--and bias in studies performed by developers and selected for this review should be minimal. Also, developers have a stake in an honest assessment of their products. The better the information they get, the better their practice and products can become. Finally, developers may be in the best position to evaluate their products. They may understand better than anyone--including potential users--the strengths and limitations of what they have developed, and they are better prepared than anyone to assess their products.

(2) One difficulty for any evaluation of an emerging technology is that there is nothing else like it. Each new technology has its own strengths and limitations. If the evaluation is held to strict instructional and experimental controls based on the older technology, the newer technology will be at a disadvantage. This problem can be ameliorated somewhat by focusing on instructional outcomes and not on what is done to accomplish these outcomes. Even in the best of situations, however, new approaches are unlikely to be used well since not enough is understood about how best to employ them. Despite all the evaluations listed, we may have yet to see an approach to instruction that uses interactive videodisc technology to best advantage.

In sum, it can be argued either that the view of interactive videodisc applications seen here is overly optimistic or overly pessimistic. At present it seems best to rely on the data we have and to conclude that interactive videodisc instruction offers genuine and demonstrable gains in instructional effectiveness over the conventional approaches we use now, even though we understand little about how these gains come about.

C. COST

Effectiveness by itself is only half the story. Military trainers, along with their civilian counterparts, are more frequently asking what their investment in instructional technology has bought in increased instructional effectiveness. Cost ratios (calculated as the ratio of experimental treatment costs over control treatment costs) were used to assess costs. Ratios in this investigation that are less than 1.0 indicate lower costs for interactive videodisc instruction than for conventional instruction.

Thirteen cost ratios are reported in Appendix A. All of these ratios are less than 1.0. Most came from studies concerned with training applications. Six of the studies involving military training reported cost ratios (Wilkinson, 1983; Cicchinelli et al., 1984; Pieper et al., 1984; Vernon, 1984; Green et al., 1986; and Winkler and Polich, in press); one of the studies (Aukerman, 1986) involving industrial training did; and one of the studies (Davis, 1985) involving higher education did. Five of the cost ratios reported are for initial investment (II), four are for operating and support costs (OS), and four for some combination of initial investment with operating and support costs. These ratios are all calculated as the costs of interactive videodisc instruction over the costs of conventional instruction. Since there are too few ratios here to provide reliable averages, the cost findings from these eight studies and 13 ratios are briefly summarized below.

Wilkinson (1983) compared the costs of using actual equipment with simulations of the equipment presented by interactive videodisc in electronics maintenance training. Hardware costs of the videodisc system were $7,180. Total software production costs were $18,700, but costs to duplicate the software were negligible so that the marginal costs for the software declined with each videodisc station equipped with it. These costs should be compared to the standard cost of $51,000 for each workstation involving actual equipment. The per unit costs of actual equipment workstations would decrease only slightly with increases in quantities purchased. The training course personnel recommended that a minimum of eight workstations be provided for student use, and the cost ratio of 0.19 reported in Appendix A for initial investment was based on the assumption that eight workstations would be purchased.

Cicchinelli et al. (1984) also compared the costs of using actual equipment versus videodisc simulations of the equipment in electronics maintenance training. Their findings indicated that the videodisc-based training system would cost slightly more than the training system using actual equipment for the first copy but that costs for subsequent copies would drop off quickly. The break-even point occurred at about 3 copies. Cicchinelli et al. included courseware preparation costs with costs for the videodisc system, but did not include courseware costs with costs for the actual equipment training system since courseware costs were unavailable. Consequently, the costs for interactive videodisc instruction were somewhat inflated relative to the costs for instruction using actual equipment.

Cicchinelli et al. considered two "scenarios" in comparing the costs of simulations using an interactive videodisc system in place of actual equipment. In one scenario they assumed that 10 actual equipment trainers were already in place and that an additional 10 were needed. The additional trainers could be videodisc systems or actual equipment. The cost ratio of videodisc systems to older (and less expensive) actual equipment was 0.94 for the additional trainers. The ratio was 0.84 for videodisc systems over newer equipment actually being installed in operational settings. A second scenario considered the costs of modifying 10 videodisc systems to reflect engineering changes in the operational equipment versus modifying the actual equipment used for training. Basically the comparison was between software changes in the videodisc instruction (15 new lessons, new technical documentation, and videodisc remastering) versus hardware changes in the actual equipment. The ratio of modification costs for videodisc instruction over actual equipment instruction in this scenario was 0.44.

Pieper et al. (1984) presented another study of simulation based on interactive videodisc versus actual equipment in electronic maintenance training. The ratio of single station initial investment costs for hardware was 0.02 for a videodisc-based approach over an actual equipment approach. The similar ratio for continuing hardware costs was also about 0.02. The overall ratio for initial investment costs including hardware, software, documentation, and administration was 0.27 for a videodisc-based approach over an actual equipment approach. The similar overall ratio for continuing costs was 0.03.

Vernon (1984) compared the effectiveness of simulation using interactive videodisc instruction with actual equipment to train soldiers to operate data communications terminals. The ratio of initial investment costs including hardware, software, and all courseware for interactive videodisc training over actual equipment training was 0.15. The ratio of continuing costs including the amortized initial investment for hardware, software, and courseware for interactive videodisc training over actual equipment training was 0.13. Considering maintenance costs alone, without the amortizing initial investment costs, the cost ratio for interactive videodisc training over actual equipment training was 0.01.

Green et al. (1986) discussed the 15-year life cycle costs for the approaches studied by Williams and Harold (1985), who compared classroom instruction alone with classroom instruction supplemented by interactive videodisc materials. Classroom instruction for both groups included use of the actual equipment, a sonar set costing $34 million per copy, on which students were learning to perform maintenance. The ratio of costs for operating the course over a 15-year period, including the initial costs of hardware, software, and courseware, was 0.05 for the substitution of about 17 hours of interactive videodisc instruction over instruction using actual equipment for that segment of the course.

Winkler and Polich (in press) compared instruction combining interactive videodisc and actual equipment with instruction using actual equipment only. Costs for actual equipment hardware were $138,000 per copy compared with $5,500 per copy for the interactive videodisc hardware. The ratio for the overall combination of initial investment and operating and support costs for interactive videodisc instruction over the costs for instruction using actual equipment was 0.17.

Aukerman (1986) considered only student and instructor time costs. She found costs of about $28.61 per learner for about 2.6 hours of instruction using interactive videodisc versus about $46.49 per learner using lectures and discussion yielding a cost ratio of 0.61 for interactive videodisc over the more conventional approach. Most of the cost differences were due to the substantially reduced amount of instructor time required for the interactive videodisc instruction--about 8.5 minutes versus 66 minutes for lecture/discussion.

Davis (1985) compared wet-laboratory facilities with videodisc-based facilities for instruction in respiration for biology. She did not include instruction preparation costs in her analysis for either of these approaches, which is not unreasonable since these costs may be nearly equal or they may be trivial compared to life cycle support costs of both instructional approaches, but she did include space preparation, personnel, supplies, and equipment costs. Assuming instruction involving three different organisms kept at three different temperatures and a need to renovate space for both instructional approaches, her cost data indicate a ratio of 0.80 for initial investment and 0.02 for operating and support.

Other studies, not summarized in Appendix A, reported useful analyses comparing the costs of interactive videodisc instruction with conventional instruction without comparing their instructional effectiveness. Doughty and Lent (1984) present one such comparison involving the actual costs of the two approaches. This comparison concerns a training facility for a large jet engine rebuilding facility. Doughty and Lent estimated the total costs for procuring, installing, and maintaining interactive videodisc instruction for this facility over a 10 year period to be $4,419,000. Three sources of major cost avoidances to be realized from installation of this interactive videodisc instruction were identified as engine failure avoidance, training cost avoidance, and staff savings. Doughty and Lent estimated the total 10 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 for delivering standardized, decentralized training to students--rather than delivering students to the training. Walker (1985) presented 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 3 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 0.35 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 0.49 for combined initial investment and operating and support costs.

As Orlansky and String (1977) suggested, an important source of cost avoidance in many training settings is student time. If the 30 percent savings they reported for students to reach threshold levels of performance using computer-based instruction also obtains for interactive videodisc instruction, and it was found in this review to be about 31 percent, then savings for some high student load courses will reach millions of dollars. A potentially greater source of savings suggested by Solomon (1986) would be reductions in the number of people the military has to support in a job category if the time needed to train people for it can be reduced. This is an intriguing suggestion, but it requires analyses beyond the scope of this review.

D. COST-EFFECTIVENESS

Interactive videodisc instruction was found to be less costly in nearly all studies that reported costs. It was also found to be more effective overall than conventional instruction. This combination of findings suggests strongly that interactive videodisc instruction may prove to be the most cost-effective alternative for instruction in many applications. However, this result is best viewed as suggestive rather than as conclusive because none of the reviewed studies examined both costs and effectiveness in a properly controlled empirical study based on a systematic model of cost inputs and effectiveness outputs.

This is a significant consideration. There are many different costs that may or may not be associated with an instructional approach. Costs reported for any approach will vary widely depending on the assumptions and procedures used to collect--or ignore--these different costs. If these assumptions and procedures are not made explicit, as they often are not, it is difficult to judge their relevance to the reader's concerns, and it is impossible to aggregate them across different studies--as we would like to do in a review such as this--and build up a composite understanding of what they might be for an approach such as interactive videodisc instruction.

Budgets are inadequate for cost estimation because they do not include all the components needed for an adequate cost accounting; they may distort true costs of a component to accord with local accounting practices; and they represent planned, not actual expenses. After-the-fact analyses of costs are inadequate for roughly the same reasons, and it is especially difficult to disaggregate costs for one purpose (e.g., cost accounting) after they have been assembled for another (e.g., production control and auditing).

Costs and effectiveness data should be drawn from the same comparative study for two reasons. First and most obviously, we need to establish the same, proper experimental controls for all conditions (i.e., the experimental and control treatments) for which cost and effectiveness data will be drawn. Second, we need to ensure that the same cost models are used for all treatments and that they are related to the same effectiveness models--which may be nothing more than end of instruction knowledge or performance, but which must be assessed using measures common to all treatments. These issues are discussed more fully by Levin (1983) and Fletcher (1990).

Nonetheless, it is a clear finding of this review that interactive videodisc instruction was observed to be both less costly and more effective across the studies found and examined. Although the cost-effectiveness of interactive videodisc instruction can vary widely depending on many factors, it appears that there will be many instances in which interactive videodisc instruction is the most cost-effective alternative.

E. TIME ON TASK

Very little direct evidence exists to indicate whether students using interactive videodisc instruction are willing or likely to spend more time in instruction or whether the time they do spend is more task centered than it is in conventional instruction. A number of studies listed in Appendix A 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 spend more time on relevant instructional tasks when they use interactive videodisc instruction. Therefore, it is not unreasonable to expect interactive videodisc instruction to increase time on task.

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. These students received increased practice without increasing the amount of total time they spent in training. This result is promising, but a single study cannot be viewed as conclusive.

F. RETENTION

Given the 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. Four of the studies in Appendix A [Young and Tosti (1981), Bunderson et al. (1984), Verano (1987), and Jones (1988)] addressed retention. All four were concerned with the retention of knowledge, and Jones also considered the retention of performance skills. Effect size (calculated from pooled standard deviations) for the single measure reported by Young and Tosti increased from −0.39 to +0.14 over a retention interval of 10 weeks. Effect sizes (calculated from pooled standard deviations) for the two measures reported by Bunderson et al. reduced from an average of about 0.59 to about 0.38 over the 1-week retention interval studied. Effect sizes (again calculated from pooled standard deviations) based on results reported by Verano for interactive videodisc instruction over "placebo", non-instruction reduced from 2.94 to 1.33 over the 4-week retention interval studied. In these three studies, the experimental groups and the control groups seem to have grown together over the retention interval. Jones reported retention data but not end of instruction achievement. Her data indicate substantial effect sizes remaining in favor of the interactive videodisc training 2-3 weeks after the instruction was completed for both knowledge and performance outcomes.

Some research suggests that retention is 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. The best results were again shown in groups who received the hands-on practice first followed by the audiovisual instruction and not the other way around. This finding seems in keeping with the informal observations of experienced military trainers that interactive videodisc instruction achieves better results in advanced training than in beginning training.

IV. SUMMARY

The results of this review and its conclusions principally concern the instructional capabilities, or functionalities, made available by interactive videodisc systems. Systems other than those that link videodisc players to computers but that provide the same instructional functionalities may achieve at least the level of effectiveness observed here. At present there is no hardware technology that can competitively provide the functionalities that interactive videodisc systems can, but digital video, digital audio, and compact disc technology are all developing rapidly and will soon claim at least some of the territory now held by interactive videodisc systems. The findings that follow are based on capabilities, not hardware, and should obtain for any system that provides the functionalities now found in interactive videodisc instruction.

A. EFFECTIVENESS

(1) Interactive videodisc instruction was successfully used to teach. The four comparisons listed in Appendix A of interactive videodisc instruction with a "placebo" treatment in which no relevant instruction was given, resulted in an average effect size calculated using pooled standard deviations of 1.39 (an increase of 50th percentile students to about 92nd percentile achievement) and an average effect size calculated using control group standard deviations of 1.55 (an increase to about 95th percentile achievement).

(2) Interactive videodisc instruction was more effective than conventional approaches to instruction. Forty-seven comparisons of interactive videodisc instruction with conventional approaches were identified for this review. As shown in Table 1 above, the average effect size for these 47 comparisons, calculated using pooled standard deviations over all instructional settings, instructional approaches, and outcomes, was found to be 0.50 (an increase for 50th percentile students to about the 69th percentile of achievement).

(3) Interactive videodisc instruction was more effective than conventional instruction in military training. Twenty-four comparisons of interactive videodisc instruction with conventional approaches to military training for subject areas that included maintenance, operator, and command training were identified for this review. As shown in Table 2 above, the average effect size for these 24 comparisons, calculated using pooled

standard deviations over all instructional approaches and outcomes, was found to be 0.38 (an increase for 50th percentile students to about the 65th percentile of achievement).

(4) Interactive videodisc instruction was more effective than conventional instruction in higher education. Fourteen comparisons of interactive videodisc instruction with conventional approaches to instruction in higher education settings were identified for this review. Over all instructional approaches and outcomes, there was an average increase in achievement calculated using pooled standard deviations of 0.69 standard deviations (an increase for 50th percentile students to about the 75th percentile of achievement).

The lower average effect sizes found for military training than for higher education may be due to a focus in military training on reaching threshold level(s) of achievement with minimum cost and time so that students who reach achievement criteria are sent on to duty assignments rather than held in the instructional setting as they are in higher education. This practice contrasts with the focus in education on maximizing achievement while holding costs constant so that all students remain in instruction for roughly the same amount of time allowing more efficient instructional approaches to yield higher levels of achievement. This possibility is supported by the effect sizes found for industrial training, which may be managed in ways more closely resembling military training than higher education. The industrial training results shown in Table 2 vary widely. However, when the effect sizes are limited to knowledge and performance outcomes alone, as they are in Table 3 above, the results from military and industrial training are much closer together and both differ markedly from higher education.

(5) Interactive videodisc instruction was equally effective for both knowledge and performance outcomes. The average effect sizes calculated using pooled standard deviations for 27 knowledge outcomes (facts, concepts, and other information students acquired) and for 20 performance outcomes (procedures, skills, and other capabilities students could demonstrate) both averaged around 0.35 standard deviations (suggesting an improvement of 50th percentile students to about the 64th percentile).

(6) The more the interactive features of interactive videodisc technology were used, the more effective the resulting instruction. This issue was examined directly by Verano (1987) who compared interactive videodisc instruction with segmented videodisc instruction and linear videodisc instruction and found consistently greater achievement with greater levels of interactivity. The issue can also be examined by comparing the overall effect sizes for Level II videodisc instruction with those found for Level III videodisc instruction. Table 6 (above) shows an average effect size of –0.70 calculated using pooled

standard deviations for 13 results from Level II videodisc instruction, which contrasts with the overall effect size of 0.50 found for 47 results for Level III videodisc instruction (Table 1). Effects of interactivity can also be examined by a comparison of the results from Wankel's (1984) study (Appendix B) with those from Stevens's (1984) study (Appendix A). Both studies used the same videodisc materials, and both tested for physics knowledge outcomes. Wankel's study used Level II videodisc materials and produced an effect size of –0.17, Stevens's study used Level III videodisc materials and produced an effect size of 0.29. The only exception to this pattern of greater achievement with greater interactivity occurred in one of Fowler's (1980) two comparisons of branched interactive videodisc instruction with linear videodisc instruction (Appendix A). This comparison resulted in an effect size of –0.28 and favored linear videodisc instruction -- the other resulted in an effect size of 0.72 and favored branched videodisc instruction. Aside from this single result, the pattern of greater achievement with greater interactivity was consistent across the studies identified for this review.

(7) Directed, tutorial approaches were more effective than stand-alone simulations in interactive videodisc instruction. This issue is addressed by the effect sizes shown in Table 4 (above). Similar results were found for knowledge outcomes, performance outcomes, and knowledge and performance outcomes combined. The effect sizes averaged around 0.70 for tutorial approaches, 0.40 for combined tutorial and simulation approaches, and 0.15 for simulations by themselves. Tutorial guidance appears to pay off. This result is consistent with a body of literature that suggests that simulators and training devices are more effective when incorporated into a complete training system than when they are used as stand-alone resources. On the other hand, the cost arguments for simulation over actual equipment use are sufficiently cogent that it may still be the most favorable alternative from a cost-effectiveness standpoint.

(8) Within-group variability of achievement was smaller in interactive videodisc instruction than in conventional instruction. In nearly every comparison of Level III interactive videodisc instruction with conventional instruction, the effect size calculated using pooled standard deviations was larger than the effect size calculated using control group standard deviations. This result suggests that achievement in the interactive videodisc groups was less variable and more equitably spread throughout the student population than it was in the conventional instruction groups. It has been suggested that one benefit of interactive over conventional instruction is that fewer students are left behind -- interactivity insures that every student receives some individualized attention and is therefore either goaded or aided into some progress toward the instructional goals. This

suggestion is supported by the findings shown in Tables 1-4. It is also anticipated by commentators on individualized instruction and aptitude-treatment interaction (e.g., Corno and Snow, 1986). If it explains the pattern of standard deviations, it will be particularly important for training settings in which the intention is to bring every student to criterion thresholds of performance in contrast to education settings in which maximizing each student's performance is more likely to be emphasized.

(9) The effectiveness of interactive videodisc instruction was greater than computer-based instruction has been found to be. Both approaches have been found to be more effective than conventional approaches to instruction, but on the basis of studies reviewed here, interactive videodisc instruction was the more effective of the two approaches. The average effect size of around 0.70 observed for interactive videodisc instruction used in colleges is considerably higher than both the average effect size of 0.26 found by Kulik and Kulik (1986) for computer based instruction in colleges and the average effect size of 0.42 found by Kulik, Kulik, and Shwalb (1986) for computer-based instruction in adult education.

Videodisc capabilities increase the hardware costs of a standard computer-based instruction system by about $2,500 and the software or instructional preparation costs by widely varying amounts depending on the type and use of visual information in the courseware. One might well argue for commensurate increases in the effectiveness of the instruction being delivered. However, these are initial investment costs only. The life cycle costs of computer-based instruction compared to videodisc instruction may differ trivially, if at all. Nonetheless, differences in costs, instructional objectives, and instructional approaches across all possible applications make blanket recommendations for one or the other of these technologies ill-advised. Recommendations concerning the use of computer-based instruction and interactive videodisc instruction in specific applications are probably best made on a case-by-case basis.

(10) It appears reasonable to conclude on the basis of these findings that interactive videodisc instruction is a promising approach for both training and education, but there was little in the reviewed studies to indicate how interactive videodisc instruction achieves its success. Generally, interactivity seemed valuable and more interactivity appeared to produce more achievement, but the nature of this relationship (i.e., how much of what sorts of interactivity produce what kinds of achievement in what amounts) remains unknown. Generally, more needs to be learned about what and how the different instructional features of interactive videodisc instruction contribute to the increased student achievement observed across the studies reviewed here.

Further, there are many outcomes such as speed of response, accuracy of response, attitude toward the subject matter, insight, transfer, and retention that either alone or in some combination may become the objectives of instruction. How different design alternatives for interactive videodisc instructio contribute quantitatively to these outcomes (i.e., how to design instruction to achieve specific outcomes) remains poorly understood at best. Follow-on research might begin with detailed examination of the interactive videodisc instruction materials identified by this review.

B. COST

Interactive videodisc instruction was found to be less costly than conventional instruction in nearly all the studies reviewed here that examined costs. All 13 cost ratios (the ratio of costs for interactive videodisc instruction over conventional instruction) reported in Appendix A are less than 1.0 indicating lower costs in every measured instance for interactive videodisc instruction. The average across these 13 cost ratios is about 0.36. Most of the low cost ratios reported in Appendix A are due to the substitution of interactive videodisc hardware and simulation software for actual equipment hardware in training. These are favorable results for the use of interactive videodisc instruction, but it should be noted that they were all calculated from different categories of costs and from a variety of cost models. It seems reasonable to conclude that interactive videodisc instruction is less costly than conventional instruction in many areas, but that specific costs savings, if any, must be determined on a case-by-case basis.

Another area of cost avoidances involves reductions in time to reach criterion levels of achievement in instruction. If students receive pay and allowances while they are in school, then student time reductions are an especially important source of cost avoidances. The average time saved across the studies covered by this review was 31percent, which matches closely the 30 percent time savings reported by Orlansky and String (1977) for computer-based instruction. With over 250,000 students involved in formal, residential training each day, these findings promise significant reductions in military training costs. The reductions in total military manpower that can result from such time savings are likely to be an additional and significant source of cost savings.

C. COST-EFFECTIVENESS

Interactive videodisc instruction was found to be both less costly in all studies that reported costs and more effective overall than the conventional approaches with which it was compared. This finding should be viewed as suggestive rather than conclusive since no studies were found that used systematic models to provide empirical data on both cost inputs and effectiveness outputs.

D. 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 instead of passively watching demonstrations on actual equipment, students can be actively engaged with equipment simulated by interactive videodisc technology--learning by doing, not learning by watching. 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.

D. RETENTION

Based on evidence presented here, there is little reason to believe that interactive videodisc instruction will have a significant effect on retention of either knowledge or performance. The four studies in Appendix A that reported retention data show a drift of both positive and negative results back to zero (i.e., to no differences in achievement between interactive videodisc instruction and conventional instruction). Post-training experiences typically influence retention of knowledge and performance in a powerful manner, and they may well wash out any effects of the instructional approach used to teach the knowledge or performance in the first place. The findings for interactive videodisc instruction in this review corroborate other Defense experiences with new training approaches. It has generally been found that their promise and payoff reside primarily in improving the efficiency of instruction, not in assuring that what is learned will be retained longer.

V. CONCLUSION

The 47 studies reviewed here indicate that for many different instructional settings and many different instructional objectives, interactive videodisc instruction is both more effective and less costly than conventional instruction. They suggest, therefore, that interactive videodisc instruction can have a significant positive impact on the productivity of resources allocated to military training and education and on the availability of people needed to operate and maintain military systems. Although more needs to be learned about how interactive videodisc instruction should be designed and employed, it should now be routinely considered and used in military training and education.

REFERENCES

Allan, D.M.E. (1989). *The effectiveness of interactive videodisc in clinical medical education*. San Diego, CA: Intelligent Images, DAROX Corporation.

Aukerman, M.E. (1986). *Effectiveness of an interactive video approach for CPR recertification of registered nurses*. (Doctoral Dissertation, University of Pittsburgh, Pittsburgh, PA) (University Microfilms No. 8620270).

Baggett, P. (1983). *Learning a procedure from multimedia instructions: The effects of film and practice*. (TR-125-ONR). Boulder, CO: Institute of Cognitive Science, University of Colorado.

Baggett, P. (1988). The role of practice in videodisc-based procedural instructions. *IEEE Transactions on Systems, Man, and Cybernetics*, 18, 487-496.

Binkin, M. (1986). *Military Technology and Defense Manpower*. Washington, DC: Brookings Institution.

Blatnik, F. and Holden, D. (1988). *A comparison of delivery systems: Textbooks compared to laser disks*. Swanton, OH: Technological Learning Center, Swanton Local Schools.

Bosco, J. (1986). An analysis of evaluations of interactive video. *Educational Technology*, *26*, 7-17.

Bosco, J. and Wagner, J. (1988). A comparison of the effectiveness of interactive laser disc and classroom video tape for safety instruction of General Motors workers. *Educational Technology*, *28*, 15-22.

Browning, P., White, W.A., Nave, G., and Barkin, P.Z. (1986). Interactive video in the classroom: A field study. *Education and Training of the Mentally Retarded*, *21*, 85-92.

Bunderson, C.V., Olsen, J.B., and Baillio, B. (1981). *Proof-of-concept demonstration and comparative evaluation of a prototype intelligent videodisc system*. Orem, UT: Learning Design Laboratories, WICAT, Inc.

Bunderson, C.V., Baillio, B., Olsen, J.B., Lipson, J.I., and Fisher, K.M. (1984). Instructional effectiveness of an intelligent videodisc in biology. *Machine-Mediated Learning*, *1*, 175-215.

Capper, J. (In press). Review of research on interactive videodisc for training. Alexandria, VA: Institute for Defense Analyses.

Cicchinelli, L.F. (1984). Evaluation of the electronic equipment maintenance trainer (EEMT): Individualized troubleshooting training. In *Proceedings of Ninth Symposium on Psychology in the Department of Defense, Colorado Springs, CO, 1984*. Denver, CO: University of Denver, Denver Research Institute. (DTIC No. AD-P003 317).

Cicchinelli, L.F., Keller, R.A., and Harmon, K.R. (1984). *Training capabilities test of electronics equipment maintenance trainer (EEMT): Findings and conclusions* (Technical Report No. 158). Orlando, FL: Training Analysis and Evaluation Group, Naval Training Equipment Center.

Clark, R.E. (1983). Reconsidering research on learning from media. *Review of Educational Research, 53*, 445-459.

Corno, L. and Snow, R. E. (1986). Adapting teaching to individual differences among learners. In M. C. Wittrock (Ed.), *Handbook of Research on Teaching* (Third Edition). New York, NY: Macmillan Publishing.

Crotty, J.M. (1984). *Instruction via an intelligent videodisc system versus classroom instruction for beginning college French students: A comparative experiment.* (AFIT/CI/NR 84-51D). Wright-Patterson AFB, OH: Air Force Institute of Technology/NR. (DTIC No. AD-A145 599). (University Microfilms No.8513797).

Crowder, N.A. (1959). Automated tutoring by means of intrinsic programming. In E.H. Galanter (Ed.), *Automatic Teaching: The State of the Art.* New York, NY: John Wiley and Sons.

Davis, B.G. (1985). *Nebraska videodisc science laboratory simulations: Executive summary (and) science lab videodiscs: Evaluation report.* Washington, DC: The Annenberg/CPB Project. (ERIC No. ED 264 821).

DeBloois, M.L. (1988). *Use and effectiveness of videodisc training.* Falls Church, VA: Future Systems, Inc.

DeBloois, M.L., Maki, K.C., and Hall, A.F. (1984). *Effectiveness of interactive videodisc training: A comprehensive overview.* Falls Church, VA: Future Systems, Inc.

Doughty, P.L. and Lent, R. (1984). Case studies of the cost justification of interactive video applications in key industries. In *Proceedings of the Sixth Annual Conference on Interactive Videodisc in Education and Training* (pp. 43-53). Warrenton, VA: Society for Applied Learning Technology.

Fletcher, J. D. (1988). An approach to achieving courseware portability. *The Videodisc Monitor, 6*, 16-17.

Fletcher, J. D. (1990). Computer-based instruction: Costs and effectiveness. In A. P. Sage (Ed.), *Concise Encyclopedia of Information Processing in Systems & Organizations.* Elmsford, NY: Pergamon Press.

Fletcher, J.D. and Rockway, M.R. (1986). Computer-based training in the military. In J.A. Ellis (Ed.), *Military Contributions to Instructional Technology.* New York, NY: Praeger Publishers.

Fowler, B.T. (1980). *The effectiveness of computer-controlled videodisc-based training.* (Doctoral Dissertation, University of Iowa, Iowa City, IA) (University Micofilms No. 8114254).

Gale, L. E. and Barksdale, K. (1989). *Using interactive videodiscs in the classroom: Research results.* Paper presented at International Symposium on Telecommunications in Education, Jerusalem, Israel.

Gay, G. (1986). Interaction of learner control and prior understanding in computer-assisted video instruction. *Journal of Educational Psychology, 78,* 225-227.

Gibbons, A.S., Lines, V., and Cavagnol, R.M. (1983). *Distributed instructional system project: Final report* (TDI-TR-83-5). Fort Monroe, VA: U.S. Army Training and Doctrine Command and Fort Bliss, TX: U.S. Army Air Defense Artillery School.

Glass, G.V. (1976). Primary, secondary, and meta-analysis of research. *Educational Researcher, 5,* 3-8.

Glass, G.V., McGaw, B., and Smith, M.L. (1981). *Meta-analysis in social research.* Beverly Hills, CA: Sage Publications, Inc.

Green, E.K., Beger, R.E., and Dunlap, S.W. (1986). *Economic analysis to support a training development options paper for AN/BQQ-5 maintenance training* (Special Report 86-002). Orlando, FL: Training Analysis and Evaluation Center, Naval Training Equipment Center.

Hannafin, M.J. (1985). Empirical issues in the study of computer-assisted interactive video. *Educational Communication and Technology Journal, 33*, 235-247.

Hasselbring, T., Fleenor, K., Sherwood, R., Griffith, D., Bransford, J., Goin, L. (1988). An evaluation of a level-one instructional videodisc program. *Journal of Educational Technology Systems, 16*, 151-169.

Hedges, L.V. and Olkin, I. (1980). Vote-counting methods in research synthesis. *Psychological Bulletin, 88*, 359-369.

Hedges, L.V. and Olkin, I. (1985). *Statistical Methods for Meta-Analysis*. Orlando, FL: Academic Press.

Hofmeister, A.M, Engelmann, S., and Carnine, D. (1986). Videodisc technology: Providing instructional alternatives. *Journal of Special Educational Technology, 7*, 35-41.

Holmgren, J.E., Dyer, F.N., Hilligoss, R.E., and Heller, F.H. (1979). The effectiveness of Army training extension course lessons on videodisc. *Journal of Educational Technology Systems, 8*, 263-274.

InfoWindow courseware catalog. (1988) Marietta, GA: IBM Educational Systems, IBM Corporation.

Jones, L.L. (1987). Videodisc laboratory for chemistry. In *Proceedings of the Optical Information Systems Conference, December, 1987* (pp. 157-165).

Jones, L.L. (1988). Enhancing instruction in the practice of chemistry with the computer-assisted interactive videodisc. *Trends in Analytical Chemistry, 7*, 273-276.

Ketner, W.D. (1984). Interactive videodisc for electronic equipment simulation. In *Proceedings of the Second Annual Conference on Interactive Instruction Delivery in Education, Training, and Job Performance*. Warrenton, VA: Society for Applied Learning Technology.

Kimberlin, D.A. (1982). The U.S. Army Air Defense School distributed instructional system project evaluation. In *Proceedings of the Fourth Annual Conference on Interactive Videodisc in Education and Training*. Warrenton, VA: Society for Applied Learning Technology.

King, F.J. (1982). Evaluation of a videodisc delivery system for teaching students to troubleshoot the AN/VRC-12 medium-powered radio series. Fort Monroe, VA: Training Developments Institute, U.S. Army Training and Doctrine Command. (DTIC No. AD-A157 890).

King, J.M. and Reeves, T.C. (1985). *Evaluation of an interactive microcomputer-videodisc delivery system for training in military operations on urbanized terrain (MOUT)*. Fort Eustis, VA: U.S. Army Training Support Center and Fort Benning, GA: U.S. Army Infantry Center and School.

Kline, J. M. and Gunning, D. R. (1979) "Human Interface -- Its Role in ATE." *ATE Newsletter, 12*, 6-7.

Kulik, C-L.C. and Kulik, J.A. (1986). Effectiveness of Computer-Based Education in Colleges. *AEDS Journal, 19*, 81-108.

Kulik, C-L.C., Kulik, J.A., and Shwalb, B. (1986). Effectiveness of computer-based instruction in adult education. *Journal of Educational Computing Research, 2*, 235-252.

Kulik, J.A., Cohen, P.A., and Ebeling, B.J. (1980) Effectiveness of programmed instruction in higher education: A meta-analysis of findings. *Educational Evaluation and Policy Analysis, 2*, 51-64.

Levenson, P.M., Morrow, J.R., and Signer, B. (1985). A comparison of noninteractive and interactive video instruction about smokeless tobacco. *Journal of Educational Technology Systems, 14*, 193-202.

Levin, H. A. (1983). *Cost Effectiveness: A Primer.* Beverly Hills, CA: Sage Publications.

Lyness, A.L. (1987). *Performance and norms of time for adult learners instructed in CPR by an interactive videodisc system.* Paper presented at the Fifth Annual Conference on Research in Nursing Education, San Francisco, CA. (ERIC No. ED 281 986).

Malec, V.M. and Luszczak, M. (1987). *Field evaluation of interactive simulation for maintenance training: SH-3 helicopter electro-mechanical bladefold system* (NPRDC TR 88-2). San Diego, CA: Navy Personnel Research and Development Center.

Maher, T.G. (1988). *Hands-on verification of mechanics training: A cost-effectiveness study of videodisc simulation.* Sacramento, CA: Bureau of Automotive Repair, California State Department of Consumer Affairs. (ERIC No. ED 290 026).

May, L.S. (1984). Corporate experience in evaluating interactive video information system courses. In *Proceedings of the Second Annual Conference on Interactive Instruction Delivery in Education, Training, and Job Performance.* Warrenton, VA: Society for Applied Learning Technology.

Military Manpower Training Report FY 1990. (1989). Washington, DC: Office of the Assistant Secretary of Defense (Force Management and Personnel).

Miller, R.L. (1987). An overview of the interactive market. In S. Lambert and J. Sallis (Eds), *CD-I and Interactive Videodisc Technology.* Indianapolis, IN: Howard W. Sams & Co.

Niemiec, R. and Walberg, H.J. (1987). Comparative effects of computer-assisted instruction: A synthesis of reviews. *Journal of Educational Computing Research*, 3, 19-37.

North, M. (1988). *Interactive videodisc training effectiveness study: Tellabs 244 Data Bridge.* Santa Monica, CA: North Communications.

Orlansky, J. and String, J. (1977). *Cost effectiveness of computer-based instruction in military training* (IDA Paper P-1375). Arlington, VA: Institute for Defense Analyses.

Phillips, T.L., Hannafin, M.J., Tripp, S.D. (1988). The effects of practice and orienting activities on learning from interactive video. *Educational Communication and Technology Journal, 36*, 93-102.

Pieper, W.J., Richardson, J.J., Harmon, K.R., Keller, R.A., and Massey, R.H. (1984). *Interactive graphics simulator: design, development, and effectiveness/cost evaluation* (AFHRL-TR-84-38). Brooks AFB, TX: Air Force Human Resources Laboratory.

Power on! New tools for teaching and learning. (1988). Washington, DC: Congress of the United States, Office of Technology Assessment.

Rosenthal, R. (1984). *Meta-analytic procedures for social research.* Beverly Hills, CA: Sage Publications, Inc.

Russell, A.A., Staskun, M.G., and Mitchell, B.L. (1985). The use and evaluation of videodiscs in the chemistry laboratory. *Journal of Chemical Education, 62,* 420-422.

Sarli, G.G., Nau, K.L., Martin, M.D., Kanitz, J., and Williams, R.C. (1988). *Interactive videodisc training: Annotated bibliography* (TRAC-WSMR-TD-21-88). White Sands Missile Range, NM: U.S. Army TRADOC Analysis Command.

Schroeder, J.E., Dyer, F.N., Czerny, P., Youngling, E.W., and Gillotti, D.P. (1986). *Videodisc interpersonal skills training and assessment (VISTA): Overview and findings, Volume 1* (ARI Technical Report 703). Fort Benning, GA: U.S. Army Research Institute Field Unit.

Schroeder, J.E., Hall, S., and Morey, J.C. (1985). Appendix M: Statistical results of the evaluation. In Schroeder, J.E., Dyer, F.N., Czerny, P., Youngling, E.W., and Gillotti, D.P. *Videodisc interpersonal skills training and assessment (VISTA): Software and evaluation details, Volume IV* (Research Note). Fort Benning, GA: U.S. Army Research Institute Field Unit.

Smith, S.G. and Jones, L.I. (1989). Images, imagination, and chemical reality. *Journal of Chemical Education, 66,* 8-11.

Smith, S.G., Jones, L.L. and Waugh, M.L. (1986). Production and evaluation of interactive videodisc lessons in laboratory instruction. *Journal of Computer Based Instruction, 13,* 117-121.

Solomon, H. (1986). *Economic issues in cost-effectiveness analyses of military skill training* (IDA Paper No. P-1897). Alexandria, VA: Institute for Defense Analyses.

Spencer, J. (1983). *IVIS Benchmark Study.* Bedford, MA: Educational Services Division, Digital Equipment Corporation.

Stevens, S.M. (1984). *Surrogate laboratory experiments: Interactive computer/videodisc lessons and their effect on students' understanding of science.* (Doctoral dissertation, University of Nebraska, Lincoln, NE) (University Microfilms No. 8428209).

Suppes, P., Fletcher, J.D., and Zanotti, M. (1976). Models of individual trajectories in computer-assisted instruction for deaf students. *Journal of Educational Psychology, 68,* 117-127.

Tiene, D., Evans, A., and Milheim, W. (1988). The instructional effectiveness of interactive video versus computer assisted instruction. *Interact Journal, 1,* 15-21.

Thorkildsen, R. (1985). Using an interactive videodisc program to teach social skills to handicapped children. *American Annals of the Deaf, 130,* 383-385.

Verano, M. (1987). *Achievement and retention of Spanish presented via videodisc in linear, segmented, and interactive modes.* (Doctoral dissertation, University of Texas, Austin, TX) (DTIC No. AD-A185 893).

Vernon, C.D. (1984). *Evaluation of interactive video disc system for training the operation of the DCT-9000 in the MOS 72G course.* Fort Eustis, VA: U.S. Army Communicative Technology Office and Fort Gordon, GA: U.S. Army Signal School. (DTIC No. AD-A157 856).

Videodisc compendium for education and training. (1988). St. Paul, MN: Emerging Technology Consultants, Inc.

Walker, R.A. (1985). Videodisc for decentralized training. In *Proceedings of the Seventh Annual Conference on Interactive Videodisc in Education and Training.* Warrenton, VA: Society for Applied Learning Technology.

Wankel, M.J. (1984). *Student performance on cognitive and content tests: A comparison of optical videodisc to laboratory learning in college physics*. (Doctoral dissertation, University of Nebraska, Lincoln, NE) (University Microfilms No. 8427916).

Williams, K.E. and Harold, L.J. (1985). *AN/BQQ-5 interactive video disc training effectiveness evaluation final report*. Orlando, FL: Naval Training Equipment Center.

Wilkinson, G.L. (1983) *An evaluation of equipment-independent maintenance training by means of a microprocessor-controlled videodisc delivery system* (Report TDI-TR-83-1). Fort Monroe, VA: U.S. Army Training and Doctrine Command (DTIC No. AD-A127-011).

Wilkinson, G.L. (1985). *Evaluation of the effectiveness and potential application of the interactive videodisc instructional delivery system within the training of SIGINT/EW systems repairers, CMF33*. Fort Eustis, VA: U.S. Army Communicative Technology Office and Fort Devens, MA: U.S. Army Intelligence School. (DTIC No. AD-A157 942).

Winkler, J.D. and Polich, J.M. (In press) *Effectiveness of interactive videodisc in Army communications training*. Santa Monica, CA: RAND Corporation.

Young, J.I. and Tosti, D.T. (1981). *The use of videodisc and microprocessor in equipment simulation* (Report TDI-TR-81-3). Fort Monroe, VA: U.S. Army Training and Doctrine Command.

APPENDIX A

STUDIES OF LEVEL III VIDEODISC INSTRUCTION

Table A-1. Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
Military Training	Electronics Maintenance	Practice on Simulated Equipment	27Exp 24Ctrl	IVD only vs AE only	Paper Test of AE Knowledge	$-.39^{S,K}$ ns	na	−6	na	Young and Tosti (1981)
										Also in
					Test Using AE	$-.31^{S,P}$ ns	na	−1		Ketner (1984)
					10-Week Retention of Knowledge	$.14^{S,R}$ ns	na	2		
						$-.19^{AX}$	na			
Military Training	Electronics Maintenance	Tutorial on Simulated Equipment	20Exp1 11Exp2 16Ctrl	CAI+IVD(Exp1) vs CAI(Exp2) vs Classroom (Ctrl)	Time to Complete Performance Test on AE	(ANOVA) na			na	Kimberlin (1982)
										Also in
				CAI+IVD vs Classroom		$2.18^{C,P}$ $p<.001$	1.59	68		Gibbons, Lines, and Cavagnol (1983)
				CAI vs Classroom		.88 $p<.05$	.76	32		
				CAI+IVD vs CAI		1.75 $p<.001$	1.42	53		
Military Training	Electronics Maintenance	Tutorial on Simulated Equipment	31Exp 28Ctrl	IVD only vs AE only	Performance Test on AE	$-.02^{C,P}$ ns	na	−11	.19 (II)	Wilkinson (1983)

Notes Concerning Effect Size:
T -- Tutorial Approach; C -- Tutorial and Simulation Approach Combined; S -- Simulation Approach; K -- Knowledge Measure; P -- Performance Measure; R -- Retention; D -- Time to Complete Instruction; KX -- Knowledge Average; PX -- Peformance Average; RX -- Retention Average; AX -- Overall Average (for K, P, R, & D Measures); I -- Interactivity Comparison; IX -- Interactivity Average; B -- Baseline Comparison; BX -- Baseline Average

Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
					Time to Complete the Above	$-.31^{C,P}$	na			
						$-.165^{PX}$	na			
Military Training	Electronics Maintenance	Tutorial on Simulated Equipment	72Exp1 72Exp2 72Ctrl	IVD/Hi+AE (Exp1) vs IVD/Lo+AE (Exp2) vs AE only(Ctrl)	Performance Test on AE	(ANOVA) $p<.001$			.94 (II&OS)	Cicchinelli, Keller, and Harmon (1984)
				IVD/Hi+AE vs AE only		$.69^{C,P}$ $p<.05$	.56	14	.84 (II&OS)	Also in Cicchinelli (1984)
				IVD/Lo+AE vs AE only		$.49^{C,P}$ ns	.46	11	.44 (II&OS)	
				IVD/Hi+AE vs IVD/Lo+AE		$.14^{C,I}$ ns	.12	2		
			25Exp1 26Exp2 23Ctrl	IVD/Hi(Exp1) vs IVD/Lo (Exp2) vs AE only (Ctrl)	Performance Test on AE	(ANOVA) ns				
				IVD/Hi vs AE only		$.32^{C,P}$ ns	.27	8		
				IVD/Lo vs AE only		$.18^{C,P}$ ns	.16	5		

Notes Concerning Effect Size:
T -- Tutorial Approach; C -- Tutorial and Simulation Approach Combined; S -- Simulation Approach; K -- Knowledge Measure; P -- Performance Measure; R -- Retention; D -- Time to Complete Instruction; KX -- Knowledge Average; PX -- Peformance Average; RX -- Retention Average; AX -- Overall Average (for K, P, R, & D Measures); I -- Interactivity Comparison; IX -- Interactivity Average; B -- Baseline Comparison; BX -- Baseline Average

Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
				IVD/Hi vs IVD/Lo		.14^C,I ns	.12	3		
				IVD/Hi(Exp1) vs IVD/Lo (Exp2) vs AE only (Ctrl)	Time to Complete the Performance Test	(ANOVA) ns				
				IVD/Hi vs AE only		–.15^C,P ns	–.13	–6		
				IVD/Lo vs AE only		–.22^C,P ns	–.23	–10		
				IVD/Hi vs IVD/Lo		.11^I ns	.09	4		
						.085^PX(HI)	.07			
						–.02^PX(LO)	–.035			
						.125^IX	.105			
Military Training	Electronics Maintenance	Tutorial on Simulated Equipment	20Exp 20Ctrl	IVD and AE vs. AE only	Time to Complete the Training	1.09^C,D $p<.001$	.90	25	na	Ketner (1984)

Notes Concerning Effect Size:
T -- Tutorial Approach; C -- Tutorial and Simulation Approach Combined; S -- Simulation Approach; K -- Knowledge Measure; P -- Performance Measure; R -- Retention; D -- Time to Complete Instruction; KX -- Knowledge Average; PX -- Peformance Average; RX -- Retention Average; AX -- Overall Average (for K, P, R, & D Measures); I -- Interactivity Comparison; IX -- Interactivity Average; B -- Baseline Comparison; BX -- Baseline Average

Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
Military Training	Electronics Maintenance	Simulated Equipment	21Exp 22Ctrl	IVD vs AE Practice	Course Knowledge Test (Paper)	$.21^{S,K}$ ns	.19	2	.27 (II) .03 (OS)	Pieper, Richardson, Harmon, Keller, and Massey (1984)
					Procedures Performance Test	$.33^{S,P}$ ns	.33	4		
					Completion Time for Above Test	$-.16^{S,P}$ ns	-.27	-5		
					Troubleshooting Performance Test	$.92^{S,P}$ $p<.005$	.93	19		
					Completion Time for Above Test	$-.08^{S,P}$ ns	-.08	-2		
						$.305^{PX}$	.23			
						$.24^{AX}$	.22			
Military Training	Electronic Equipment Operation	Equipment Simulation	76Exp 74Ctrl	IVD vs AE Practice	Performance Test 1 with AE	$.33^{S,P}$ $p<.05$	.36	7	.15 (II)	Vernon (1984)
					Completion Time for Above Test	$.77^{S,P}$ $p<.001$	.83	2	.13 (OS)	

Notes Concerning Effect Size:
T -- Tutorial Approach; C -- Tutorial and Simulation Approach Combined; S -- Simulation Approach; K -- Knowledge Measure; P -- Performance Measure; R -- Retention; D -- Time to Complete Instruction; KX -- Knowledge Average; PX -- Peformance Average; RX -- Retention Average; AX -- Overall Average (for K, P, R, & D Measures); I -- Interactivity Comparison; IX -- Interactivity Average; B -- Baseline Comparison; BX -- Baseline Average

Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
					Performance Test 2 with AE	.02^{S,P} ns	.03	0		
					Completion Time for Above Test	.34^{S,P} p<.05	.31	8		
						.365^{PX}	.38			
Military Training (Infantry Officers)	Military Operations on Urbanized Terrain (MOUT)	Simulated Recon- naissance Using Sur- rogate Travel	169Exp 156Ctrl	IVD vs Conventional Training	Existing MOUT Per- formance Test	.16^{S,P} ns	.15	2	na	King and Reeves (1985)
			148Exp 150Ctrl		MOUT Simulation Test	.71^{S,P} p<.05	.74	10		
			148Exp 150Ctrl		Defense Deployment Test	.34^{S,K} p<.05	.40	19		
Military Training	Electronics Maintenance	Tutorial with Simulated Equipment	48Exp 51Ctrl	IVD+AE vs AE Practice	Paper Test of Knowledge	.20^{C,K} ns	.19	1	na	Wilkinson (1985)
					Performance Test on AE	.37^{C,P} ns	.31	5		
					Time to Complete Test on AE	−.33^{C,P} ns	−.39	−12		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
						$.02^{PX}$	−.04			
						$.08^{AX}$	.04			
Military Training	Sonar Maintenance	Tutorial on Simulated Equipment	8Exp 8Ctrl	IVD and AE vs. AE only	Test on AE Procedure I	$.29^{C,P}$ $p<.05$	na	39	See next reference	Williams and Harold (1985)
					Time to Complete Procedure I	$.75^{C,P}$ $p<.001$	na	40		
					Test on AE Procedure II	na ns	na	33		
					Time to Complete Procedure II	$2.27^{C,P}$ $p<.001$	na	28		
						1.10^{PX}	na			
Same	Same	Same	Same	na	Same	15 year life-cycle costs		na	.05 (II & OS)	Green, Beger, and Dunlap (1986)
Military Training	Interpersonal Skills	Simulated Interpersonal Situations with Tutorial Feedback	30Exp1 31Ctrl1 29Ctrl2	IVD(Exp) vs Role Play (Ctrl1) vs Programmed Text(Ctrl2)	Content Test1 (Verbal Abuse)	ANOVA ns			na	Schroeder, Dyer, Czerny, Youngling, and Gillotti (1986)
				IVD vs Role Play		$.54^{C,K}$ ns	.53	19		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
				IVD vs Prog. Text		$.31^{C,K}$ ns	.31	10		Also in Schroeder, Hall, and Morey (1985)
						$.425^{KX}$	.42			
			19Exp 17Ctrl1 18Ctrl2	IVD vs Role Play vs Prog. Text	Content Test2 (Taking Charge)	ANOVA ns				
				IVD vs Role Play		$.68^{C,K}$ ns	.85	25		
				IVD vs Prog. Text		$.65^{C,K}$ ns	.61	29		
						$.665^{KX}$	.73			
			11Exp 14Ctrl1 13Ctrl2	IVD vs Role Play vs Prog. Text	Content Test3 (Meeting the Troops)	ANOVA ns				
				IVD vs Role Play		$-.30^{C,K}$ ns	−.26	−11		
				IVD vs Prog. Text		$.05^{C,K}$ ns	.05	1		
						$-.125^{KX}$	−.105			

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
			15Exp 14Ctrl1 15Ctrl2	IVD vs Role Play vs Prog. Text	Content Test4 (Performance Counseling)	ANOVA ns				
				IVD vs Role Play		$-.16^{C,K}$ ns	−.17	−6		
				IVD vs Prog. Text		$.69^{C,K}$ ns	.74	33		
						$.265^{KX}$	.285			
			14Exp 16Ctrl1 15Ctrl2	IVD vs Role Play vs Prog. Text	Content Test5 (Insubordina- tion)	ANOVA $p<.05$				
				IVD vs Role Play		$.88^{C,K}$ $p<.05$	1.12	43		
				IVD vs Prog. Text		$.78^{C,K}$ $p<.05$	.97	38		
						$.83^{KX}$	1.045			
			14Exp 13Ctrl1 14Ctrl2	IVD vs Role Play vs Prog. Text	Content Test6 (Personal Crisis)	ANOVA ns				
				IVD vs Role Play		$-.46^{C,K}$ ns	−.45	−12		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
				IVD vs Prog. Text		$-.18^{C,K}$ ns	−.16	−6		
						$-.32^{KX}$	−.305			
Military Training	Helicopter Maintenance (Hydraulics)	Tutorial on Simulated Equipment	36Exp 35Ctrl	Compulsory Independent Study with vs without IVD	Paper Test of of Course Knowledge	$.48^{C,K}$ $p<.05$	na	4	na	Malec and Luszczak (1987)
					Performance Test Using Training Device	$.14^{C,P}$ ns	na	2		
						$.31^{AX}$	na			
Military Training	Electronic Equipment Operation	Tutorial with Simulated and Actual Equipment	169Ctrl 167Exp	IVD with Actual Equipment vs Actual Equipment Only	Performance Test (IF Gain Alignment) Using AE	$-.03^{C,P}$ ns	−.03	−4	.17 (II &OS)	Winkler and Polich (In press)
					Performance Test (AGC Alignment) Using AE	$.09^{C,P}$ ns	.09	11		
					Performance Test (Squelch Adjustment) Using AE	$-.09^{C,P}$ ns	−.08	−4		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
					Knowledge Test (Paper)	$-.07^{C,K}$ ns	−.08	−1		
						$-.01^{PX}$	−.01			
						$-.025^{AX}$	−.025			
			211Ctrl 217Exp	IVD with Actual Equipment vs Actual Euipment Only	Performance Test Errors Using AE Simulator	$.18^{C,P}$ ns	.19	14	na	
					Time to Complete Performance Test Using AE Simulator	$.14^{C,P}$ ns	.13	7		
					Trials to Complete Performance Test Using AE Simulator	$.21^{C,P}$ $P<.05$	.18	18		
						$.18^{PX}$	.17			
Industrial Training	Electronics Maintenance	Tutorial with Simulated Equipment	15Exp 14Ctrl	IVD vs Linear Videotape & Workbook	Time to Complete Course A	$1.03^{C,D}$ $p<.001$	na	35	na	Spencer (1983)

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
			7Exp 16Ctrl		Time to Complete Course B	$.94^{C,D}$ $p<.05$	na	23	na	Also in May (1984)
			13Exp 12Ctrl		Time to Complete Course C	$1.12^{C,D}$ $p<.001$	na	47	na	
Industrial Training	CPR Recertification Training for Registered Nurses	Simulation and Sensored Manikin	15Exp 14Ctrl	IVD vs Lecture (Acute Care)	Knowledge Test	$-.90^{S,K}$ ns	−1.14	−4	.61 (OS)	Aukerman (1986)
			14Exp 14Ctrl	IVD vs Lecture (Non-Acute Care)	Knowledge Test	$.00^{S,K}$ ns	.00	0		
			15Exp 14Ctrl	IVD vs Lecture (Acute Care)	Skill Test	$-.02^{S,P}$ ns	−.07	−1		
			14Exp 13Ctrl	IVD vs Lecture (Non-Acute Care)	Skill Test	$.07^{S,P}$ ns	.07	1		
Industrial Training	Communication Circuit Maintenance	Tutorial with Equipment Simulation	10Exp 10Ctrl1 12Ctrl2	IVD(Exp) vs Classroom(Ctrl1) vs On-Job Trng (Ctrl2)					na	North (1988)

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
				IVD vs Classroom	Equipment Knowledge	$.76^{C,K}$ p<.05	.75	20		
				IVD vs On-Job Trng		$1.53^{C,K}$ p<.001	1.42	58		
				Classroom vs On-Job Trng		.82 p<.05	.77	31		
						1.145^{KX}	1.085			
Industrial Training	Handling of Hazardous Materials	Tutorial	105Exp 104Ctrl	IVD vs Videotape	Errors on Content Test	$1.20^{T,K}$ P<.001	1.10	47	na	Bosco and Wagner (1988)
Higher Education	Equipment Operation (16mm Projector)	Tutorial	30Exp1 30Exp2 30Ctrl1 30Ctrl2	Branched IVD (Exp1) vs Linear IVD (Exp2) vs Branched Video-tape(Ctrl1) vs Linear Videotape (Ctrl2)	Recall of Device Component Names	ANOVA (Delivery System p<.001) (Branching ns)			na	Fowler (1980)
				Branched IVD vs Linear IVD	$-.28^{T,I}$	−.28 ns		−3		
				Branched IVD vs Branched Videotape	$.85^{T,K}$	.70 p<.01		15		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
				Branched IVD vs Linear Videotape	.27[T,K]	.21 ns	5			
				Linear IVD vs Branched Videotape		1.07 $p<.01$	.88	19		
				Linear IVD vs Linear Videotape		.46 ns	.36	8		
				Branched Videotape vs Linear Videotape		−.41 ns	−.38	−9		
					Instruction Completion Time	ANOVA (Delivery System $p<.001$) (Branching ns)				
				Branched IVD vs Linear IVD		−.04[T,I] ns	−.05	−1		
				Branched IVD vs Branched Videotape	1.68[T,D]	1.51 $p<.01$	27			
				Branched IVD vs Linear Videotape	.97[T,D]	.84 $p<.01$	18			
				Linear IVD vs Branched Videotape		1.77 $p<.01$	1.54	27		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
				Linear IVD vs Linear Videotape		1.04 p<.01	.88	19		
				Branched Videotape vs Linear Videotape		–.59 p<.05	–.57	–12		
						.56^KX	.455			
						1.325^DX	1.175			
						.94^AX	.815			
						–.16^IX	–.12			
			28Exp1 27Exp2 24Ctrl1 23Ctrl2	Opeartion, Fault Location, and Transfer	ANOVA (Delivery System p<.05) (Branching p<.01)					
				Branched IVD vs Linear IVD	.72^T,I	.75 p<.05		16		
				Branched IVD vs Branched Videotape	.59^T,P	.58 p<.05		13		
				Branched IVD vs Linear Videotape	1.02^T,P	.99 p<.01		26		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
				Linear IVD vs Branched Videotape		−.10 ns	−.09	−2		
				Linear IVD vs Linear Videotape		.36 ns	.34	9		
				Branched Videotape vs Linear Videotape		.43 ns	.43	11		
						.805^{PX}	.785			
Higher Education	Biology "Development of Living Things"	··torial	25Exp 24Ctrl	IVD vs Lecture (Student Volunteers)	Biology Knowledge (Objective Test)	.30^{T,K} ns	.27	8	na	Bunderson, Baillio, Olsen, Lipson, and Fisher (1984)
					Biology Knowledge (Short Answer Test)	.88^{T,K} $p<.05$	.93	73		Also in Bunderson, Olsen, and Baillio (1981)
					1 Wk Retention (Objective Test)	.27^{T,R} ns	.29	6		
					1 Wk Retention (Short Answer Test)	.49^{T,R} ns	.53	36		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
					Learning Time	$.78^{T,D}$ ns	.60	32		
						$.59^{KX}$	.60			
						$.38^{RX}$	.41			
						$.54^{AX}$	.52			
			28Exp 25Ctrl	IVD vs Lecture (Utah) (Random Assignment)	Biology Knowledge (Objective Test)	$.47^{T,K}$ $p<.05$	.88	18	na	
					Biology Knowledge (Short Answer Test)	$.64^{T,K}$ $p<.05$	.58	37		
					Learning Time	$2.04^{T,D}$ $p<.05$	2.12	44		
						$.555^{KX}$	.73			
						1.05^{AX}	1.19			

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
			24Exp 73Ctrl	IVD vs Lecture (Texas) (Random Assignment)	Biology Knowledge (Objective Test)	$.81^{T,K}$ p<.05	.45	6	na	
					Biology Knowledge (Short Answer Test)	$.58^{T,K}$ p<.05	.59	17		
					Learning Time	$1.10^{T,D}$ p<.05	1.13	32		
						$.695^{KX}$	.52			
						$.83^{AX}$	.72			
Higher Education	Foreign Language (Beginning French)	Tutorial	26Exp 26Ctrl1 26Ctrl2	IVD(Exp1) vs Classroom(Ctrl1) vs No Instruction (Ctrl2)	Course Knowledge (Multiple Choice Items)	(ANOVA) p<.001			na	Crotty (1984)
				IVD vs Classroom		$.08^{T,K}$ ns	.09	2		
				IVD vs No Instruction		$1.23^{T,B}$ p<.05	1.50	31		
				Classroom vs No Instruction		1.31 p<.05	1.40	29		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
				IVD vs Classroom vs No Instruction	Course Knowledge (Completion Items)	(ANOVA) $p<.001$				
				IVD vs Classroom		$1.16^{T,K}$ $p<.05$	1.02	64		
				IVD vs No Instruction		$2.58^{T,B}$ $p<.05$	2.52	294		
				Classroom vs No Instruction		1.03 $p<.05$	1.20	139		
						$.62^{KX}$	.555			
						1.905^{BX}	2.01			
Higher Education	Physics "Puzzle of the Tacoma Bridge Collapse"	Simulated Laboratory	21Exp 16Ctrl	IVD vs Laboratory Equipment	Physics Knowledge	$.29^{S,K}$ ns	.29	11	na	Stevens (1984)
			22Exp 19Ctrl		Scientific Attitudes	.26 ns	.24	2		
Higher Education	Biology (Respiration)	Simulated Laboratory	22Exp 8Ctrl	IVD Lab vs Traditional Lab	Content Test (Paper)	$-.29^{S,K}$ ns	−.34	−8	.80 (II)	Davis (1985)
									.02 (OS)	
	Biology		22Exp	Same	Same	$1.06^{S,K}$	.83	23	na	

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
	(Climate and Life)		25Ctrl			p<.01				
Higher Education	Chemistry (Kinetics and Equilibrium)	Tutorial with Simulated Laboratory	26Exp 23Ctrl	IVD+Lab vs Lab only	Chemistry Knowledge (Lab Reports)	$.69^{C,K}$ p<.05	na	17	na	Smith, Jones, and Waugh (1986)
			21Exp1 17Exp2 49Ctrl	IVD(Exp1) vs IVD+Lab (Exp2) vs Lab only (Ctrl)	Course Knowledge	(ANOVA) p<.001	na		na	
				IVD vs Lab only		$1.16^{C,K}$ p<.05	1.08	40		
				IVD+Lab vs Lab only		$1.00^{C,K}$ p<.01	.94	34		
				IVD+Lab vs IVD		.19 ns	.19	4		
						1.08^{KX}	1.01			
Higher Education	Chemistry (Kinetics and Equilibrium)	Tutorial with Simulated Laboratory	25Exp 27Ctrl	IVD vs Lab	Course Knowledge	$.65^{C,K}$ p<.05	.66	22	na	Jones (1987) Also in Smith and Jones (1989)
Higher Education	Public Health (CPR Instruction)	Simulation and Sensored Manikin	48Exp 51Ctrl	IVD vs Classroom Instruction	Course Knowledge	$.35^{S,K}$ ns	na	2	na	Lyness (1987)
					Performance	$.39^{S,P}$	na	47		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
					(Single Rescuer)	ns				
					Performance (Two Rescuer)	$.23^{S,P}$ ns	na	19		
					Performance (Obstructed Airway #1)	$.41^{S,P}$ $p<.05$	na	23		
					Performance (Obstructed Airway #2)	$.80^{S,P}$ $p<.05$	na	63		
					Performance (Obstructed Airway #3)	$.67^{S,P}$ $p<.05$	na	59		
					Performance (Infant)	$-.27^{S,P}$ ns	na	-23		
					Performance (Infant Obstructed Airway #1)	$-.31^{S,P}$ ns	na	-12		
					Performance (Infant Obstructed Airway #2)	$.08^{S,P}$ ns	na	6		
						$.25^{PX}$	na			

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
						$.26^{AX}$	na			
Higher Education	Foreign Language (Beginning Spanish)	Tutorial	23Exp1 23Exp2 23Exp3 23Ctrl	IVD Linear (Exp1) vs IVD Segmented (Exp2) vs IVD Interactive (Exp3) vs Irrelevant Instruction(Ctrl)	Course Knowledge	(ANOVA) $p<.001$			na	Verano (1987)
				IVD Interactive vs IVD Segmented		$1.36^{T,I}$ $p<.001$	1.41	33		
				IVD Interactive vs IVD Linear		$2.16^{T,I}$ $p<.001$	2.49	58		
				IVD Segmented vs IVD Linear		$.72^{T,I}$ ns	.80	18		
				IVD Interactive vs Irrelevant Inst.	$p<.01$	$2.94^{T,B}$	3.84	88		
				IVD Segmented vs Irrelevant Inst.	$p<.05$	$1.44^{T,B}$	1.80	41		
				IVD Linear vs Irrelevant Inst.		.75 ns	.83	19		
				IVD Interactive vs IVD	Course Knowledge	$.74^{T,I}$ $p<.001$	.79	30		

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Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
				Segmented	(4 Wk Delay)					
				IVD Interactive vs IVD Linear		$1.41^{T,I}$ p<.001	2.24	56		
				IVD Segmented vs IVD Linear		$.56^{T,I}$ ns	.82	21		
				IVD Interactive vs Irrelevant Inst.	p<.001	$1.33^{T,B}$	2.06	51		
				IVD Segmented vs Irrelevant Inst.	ns	$.47^{T,B}$	.68	17		
				IVD Linear vs Irrelevant Inst.		−.13 ns	−.12	−3		
						1.16^{IX}	1.425			
						1.545^{BX}	2.095			
Higher Education	Chemistry (Gas Analysis)	Tutorial with Simulated Laboratory	26Exp 22Ctrl	IVD vs Lab	Spectrometer Usage - Score (3 Wk Delay)	$1.50^{C,R}$ p<.01	1.08	69	na	Jones (1988)
					Spectrometer Usage - Time to Complete (3 Wk Delay)	$1.37^{C,R}$ p<.01	1.09	39		

Notes Concerning Effect Size:
T -- Tutorial Approach; C -- Tutorial and Simulation Approach Combined; S -- Simulation Approach; K -- Knowledge Measure; P -- Performance Measure; R -- Retention; D -- Time to Complete Instruction; KX -- Knowledge Average; PX -- Peformance Average; RX -- Retention Average; AX -- Overall Average (for K, P, R, & D Measures); I -- Interactivity Comparison; IX -- Interactivity Average; B -- Baseline Comparison; BX -- Baseline Average

Table A-1 (Continued). Studies of Level III Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
					Knowledge Test (2 Wk Delay)	$.50^{C,R}$ p<.01	.51	10		
						1.12^{RX}	.89			
Higher Education	Medical Education (Trauma)	Simulated Patient with Critique of Student Performance	33 Exp 31 Ctrl	Standard Instruction with vs without IVD (1 IVD Program)	Knowledge Test (Paper)	$1.01^{S,B}$ p<.01	.97	16	na	Allan (1989)
			28 Exp 40 Ctrl	Standard Instruction with vs without IVD (4 IVD Programs)	Knowledge Test (Paper)	$1.09^{S,B}$ p<.01	1.12	20		

Notes Concerning Effect Size:
T -- Tutorial Approach; C -- Tutorial and Simulation Approach Combined; S -- Simulation Approach; K -- Knowledge Measure; P -- Performance Measure; R -- Retention; D -- Time to Complete Instruction; KX -- Knowledge Average; PX -- Peformance Average; RX -- Retention Average; AX -- Overall Average (for K, P, R, & D Measures); I -- Interactivity Comparison; IX -- Interactivity Average; B -- Baseline Comparison; BX -- Baseline Average

APPENDIX B

STUDIES OF LEVEL II VIDEODISC INSTRUCTION

Table B-1. Studies of Level II Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
Military Training	Armor Concepts	Slide/Tape Tutorial	16Exp 31Ctrl	IVD vs Slide/Tape	Performance Test	-2.42^P p<.05	−2.69	−17	na	Holmgren, Dyer, Hilligoss, and Heller (1979)
	Artillery Concepts		8Exp 33Ctrl			$.69^P$ ns	.85	8		
	Infantry Concepts		17Exp 31Ctrl			-2.25^P p<.05	−2.70	−18		
	Armor Concepts		16Exp 31Ctrl	IVD with Review vs Slide/Tape	Performance Test	-2.83^P p<.05	−3.08	−20		
	Artillery Concepts		23Exp 33Ctrl			$-.65^P$ ns	−.69	−7		
	Infantry Concepts		15Exp 31Ctrl			-1.93^P p<.05	−2.20	−15		
Military Training	Electronics Maintenance	Slide/Tape Tutorial with	72Exp 163Ctrl	IVD vs Slide/Tape	Paper Test of Knowledge	$-.07^K$ ns	na	−1	na	King (1982)
		Actual Equipment	72Exp 163Ctrl		Lesson Completion Time 1	$.29^D$ p<.05	na	9		
			70Exp 158Ctrl		Lesson Completion Time 2	$-.36^D$ p<.05	−.40	−11		

Notes Concerning Effect Size:
K -- Knowledge Measure; P -- Performance Measure; D -- Time to Complete Instruction

Table B-1 (Continued). Studies of Level II Videodisc Instruction.

Instructional Setting	Instructional Content	Instructional Approach	N	Comparison	Outcome	ES Comb SD	ES Ctrl SD	% Impr.	Cost Ratio	Reference
			69Exp 157Ctrl		Lesson Completion Time 3	$-.13^{D}$ ns	–.17	–7		
Higher Education	Physics "Puzzle of the Tacoma Bridge Collapse"	Simulated Laboratory	18Exp 18Ctrl	IVD vs Laboratory Equipment	Physics Knowledge (Standing Waves)	$-.17^{K}$ ns	na	–4	na	Wankel (1984)
Higher Education	Chemistry	Tutorial with Simulated Laboratory	58Exp 54Ctrl	IVD vs Videotape	Course Knowledge	$.39^{K}$ $p<.05$	.47	56	na	Russell, Staskun, and Mitchell (1985)
			57Exp 55Ctrl		Graphical Analysis	$.31^{K}$ ns	.30	10		

Notes Concerning Effect Size:
K -- Knowledge Measure; P -- Performance Measure; D -- Time to Complete Instruction