DOCUMENT RESUME

ED 228 989 IR 010 658

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TITLE Proof-of-Concept Demonstration and Comparative Evaluation of a Prototype Intelligent Videodisc System. Final Report.
INSTITUTION WICAT, Inc., Orem, Utah.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE 2 Jan 81
GRANT SED-790000794
NOTE 74p.
PUB TYPE Reports - Descriptive (141)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Biology; Computer Assisted Instruction; Delivery Systems; Feasibility Studies; Higher Education; Instructional Materials; Media Research; Program Evaluation; *Science Instruction; *Student Attitudes; *Teaching Methods; *Videodisc Recordings
IDENTIFIERS *Intelligent Videodisc Systems; Interactive Systems

ABSTRACT

This report summarizes the results of a 22-month proof-of-concept demonstration of a class of interactive videodisc systems, which involved the use of an intelligent videodisc in developmental biology instruction at the undergraduate level. The study involved the development of hardware, software, courseware, and instructional strategies for videodisc instruction and included evaluation of this development through three stages of complexity: (1) a manual videodisc system; (2) a manual videodisc enhanced with menus and branching for learner-controlled access, with scoring and status information, and with answer judging for the practice problems; and (3) the development and use of a new videodisc which added additional content--especially in the areas of simulation and games, an interactive glossary, and more complex programming for learner-controlled data access. National needs for innovation in science education are discussed in the context of the promise of intelligent videodisc systems. Issues and observations dealing with hardware, software, courseware, and theory are then presented, while the major part of the report deals with the extensive evaluation results for the three phases of videodisc sophistication. The report concludes with a look into the future of such systems. (LMM)

Final Report

Proof-of-Concept Demonstration and Comparative Evaluation of a Prototype Intelligent Videodisc System

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2 January 1981

This work is supported by NSF Grant
No. SED-790000794
The views expressed are those of the authors

APPENDIX D

NATIONAL SCIENCE FOUNDATION Washington, D.C. 20550	FINAL PROJECT REPORT NSF FORM 98A	
PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING		
PART I—PROJECT IDENTIFICATION INFORMATION		
1. Institution and Address WICAT Inc. 1160 S. State #10 Orem, UT 84057	2. NSF Program Intelligent Videodisc Sol 4. Award Period From 4/1/79 To 9/30/81	3. NSF Award Number c. SED-7900794 5. Cumulative Award Amount $386,971
6. Project Title An Intelligent Videodisc System: Evaluation in Developmental Biology.		

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

This project was designed to develop and evaluate a flexible, intelligent videodisc system using technology that will be typical of center-stream hardware in the next five years. The intelligent videodisc system consisted of a computer, a videodisc player, an interface between videodisc player and computer, a color TV monitor, a medium resolution graphics CRT, and a keyboard with special learner control keys plus standard typewriter keys.

The course material supported instruction in developmental biology on the university and college level. Besides basic conceptual instruction the videodisc lesson included laboratory guides and simulations, micrograph files, vocabulary games and drill and practice instruction in scientific notation.

The evaluation design called for the comparison of student achievement and affect with the videodisc vs. classroom control groups. Briefly, the results showed that students scored significantly higher on a reliable post-test after videodisc instruction than students who received the instruction from classroom lecture and textbook. The average total study time taken by the videodisc group was about 30% less than the time required by the classroom groups. Student affect was very high to the extent that some students actually changed their attitudes toward biology in a positive direction.

In short, the delivery of science instruction via intelligent videodisc has proven not only feasible, but superior in some situations to traditional college science instruction. The authors explain in the final report how intelligent videodisc systems can make a significant contribution to reversing some of the negative trends in science education.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM: Check (√)	TO BE FURNISHED SEPARATELY TO PROGRAM: Approx. Date
a. Abstracts of Theses					
b. Publication Citations					
c. Data on Scientific Collaborators					
d. Information on Inventions					
e. Technical Description of Project and Results					
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
C. Victor Bunderson	C. Victor Bunderson	3/30/81

NSF Form 98A (5-78) Supersedes All Previous Editions — Form Approved OMB No. 99R0011

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INTRODUCTION

This is the final report of a 22-month "proof of concept demonstration" of a class of interactive videodisc systems. This is one of two projects funded by the National Science Foundation in 1979. It involves an intelligent videodisc in developmental biology. By intelligent videodisc system is meant an optical videodisc having all of the features of optical videodisc players, viz random access, freeze frame, variable speed motion, and the large storage capacity of 54,000 individual video frames. These systems, when interfaced with a powerful microprocessor, become "intelligent" in that the random accessing can be based on complex algorithms or on learner choice. The computer can keep score, provide answer analysis, answer judging, simulations, games, overlay of computer-generated information on the video screen, and many other features heretofore not possible with videotape machines alone or computer-assisted instruction alone.

This study involved the development of hardware, software, courseware, and instructional strategies for videoidsc instruction. This development was evaluated through three stages of complexity. The first stage (Phase I) was a manual videodisc system developed by WICAT Incorporated in cooperation with McGraw-Hill for the Magnavox videodisc player with automatic stop feature. This disc used a rule-example-practice instructional strategy and the rich visuals available from some existing McGraw-Hill films on biological development. In Phase II, the manual videodisc was enhanced with menus and branching for learner controlled access, with scoring and status information, and with answer judging for the practice problems. In Phase III, a new videodisc was developed which covered the same content as the Phase I and Phase II systems but added additional content, especially in the areas of simulations and games. An interactive glossary was added, and much more complex learner controlled branching and accessing of the data on the disc was programmed. In addition, more complex scoring and status information displays were provided and more sophisticated answer judging.

This final report first puts national needs for innovation in science education in context with the promise of intelligent videodisc systems, then reports certain observations about issues dealing with hardware, software, courseware, and theory. The bulk of this paper deals with the evaluation results for the three phases of videodisc sophistication. The report concludes with a look into the future.

NATIONAL NEEDS FOR INNOVATION IN SCIENCE EDUCATION

There is a growing discrepancy between the needs of our society for scientists and technical personnel and the educational accomplishments of the entering labor pool. The authors of this paper have had the opportunity to observe this problem closely in three sectors: military education and training, industrial education and training, and public education. In the first two cases there are several major driving forces behind the problems, but the two most important are:

(1) The introduction of more and more advanced technology into job requirements, demanding increasingly high levels of understanding and ability in operations and maintenance,

(2) Changes in the educational accomplishments of the labor pool, particularly reduced science, technical, and mathematical literacy.

In the military, these needs are alarming. This decade will see the greatest influx of new equipment ever, but our enlisted people cannot satisfactorily operate or maintain much of the equipment we have now. These problems are elaborated in numerous sources, including Bunderson (1980).

In industry, the authors and their colleagues at WICAT have worked with numerous industrial companies who are struggling with technological obsolescence of their existing scientists, engineers, and technicians, and with the lack of adequate technical education in the available labor pool. To meet the challenge of foreign competition, the auto makers and others are introducing the greatest changes in equipment design and maintenance procedures in history. Even formerly labor-intensive operations like office work are witnessing profound changes due to the introduction of technology. Major corporations have found it necessary to teach reading to thousands of employees, and corporations collectively spend billions upgrading the technical know-how of their more advanced employees, but these billions barely dent the problem.

In public education, NSF has recently published a report entitled "Science and Engineering Education for the 1980's and Beyond." This report tells the same sad story: we as a nation are becoming technologically illiterate. There is a growing discrepancy between the education high school and college students are getting and the requirements for scientific, technical, and mathematical literacy of the jobs in their future.

NSF has also recently completed an 8-volume status study of pre-college science, mathematics, and social studies education. This needs assessment study involved three independent but interrelated investigations (Weiss, 1977; Helgeson, Blosser and Howe, 1978; Stake and Easley, 1978). Some of the needs found in these studies were as follows:

(1) Science education is not seen as among the "basics" by either school administrators or teachers. As a result, it gets low priority. A national survey noted that "fewer than half of the nation's elementary school children are likely to have even a single year in which their teacher will give science a significant share of the curriculum and do a good job of teaching.

(2) Science is presented primarily through verbal abstractions. Instruction is usually taken from a textbook and the method is read--recite--test--discuss. Over 50 percent of the teachers use only a single textbook and from 20-25 percent reported that their textbooks were over five years old. The curriculum does not venture beyond the boundaries set by the texts, and the majority of texts are content and fact oriented rather than concept, principle, and process oriented.

Students infrequently have opportunities for learning in ways other than through reading, lecture, and recitation. Nine percent of the K-12 classes never use laboratory materials; fourteen percent use laboratory less than once a month. At the secondary level, only twenty-six percent of high school classes and thirty-eight percent of junior high school classes have laboratory learning as often as once a week.

(3) There is a lack of motivation and interest in science and mathematics. This is not surprising in light of the dominance of verbal abstractions about contents and facts to be memorized, and the increasingly low priority being given to science and math by school administrators and teachers.

Other indicators of the lack of motivation and interest are that science enrollments in high school and college are declining. Only forty-five percent of high school students have taken a one-year general biology course; less than sixteen percent take a one-year chemistry course, and less than nine percent take a one-year physics class. The number of college degrees in science is declining in all areas of science except medicine (National Science Foundation data book, 1980).

Increasingly, due to lack of qualified teachers, declining student interest, lack of proper equipment, and budget restrictions, school districts are dropping science and math courses as requirements for graduation. This sorry picture is in sharp contrast to the Soviet Union's progress.

The Soviet Union is making an intensive effort to educate its entire population in science and technology. The majority of students in colleges are studying engineering and science-oriented disciplines. In a study by Wirtzup (1980) it was noted that "all Soviet youngsters are required to complete five years of physics, including for example an introduction to Einstein's special theory of relativity and four years of chemistry (including a full year of organic chemistry). Over five million graduates of Soviet secondary educational institutions in 1978 and 1979 have studied calculus for two years while 105,000 United States high school students have taken a one-year calculus course. . . the American one-year geometry course offers but a very small fraction of the Soviet ten year geometry curriculum". By way of summary, the Soviet education system provides for one or two more years of calculus, four more years training in physics, three more years in chemistry, three and a half more years in biology, one year more in astronomy, three years more in mechanical drawing, and six to ten years more training in workshop or hands-on laboratory work.

The Promise of Interactive Videodisc in Science Education

The national needs discussed in the last section, particularly the first one, depend for their solution on a shift in national priorities. The importance of properly educating our populous for the world they will live in must become important both to leaders and to the voting public as a whole. The new videodisc and microcomputer technologies cannot bring about such a shift in national priorities among government leaders, parents, and school administrators and teachers, but it can offer a significant tool in the eventual solution to the problems. Consider the following:

(1) The interactive videodisc can replicate instruction for both groups and individuals. This replicated instruction is interactive, visual, and experiential rather than verbal-abstract. The 54,000 individual still frames of videodisc can be filled with interesting motion sequences, color still frames showing all manner of scientific phenomena and equipment, terse well-designed text with graphics, and most of all, interactions to show what happens under a variety of experimental or exploratory variations selected by the students. Textbooks now

control the curriculum but do not provide the rich visuals, the simulations, and the interactions. Teachers must provide this, but even the better teachers mention most frequently that they need the following:

(a) opportunities to learn about new teaching materials,
(b) open access to current information and experts in their fields,
(c) opportunities to learn new teaching methods, especially regarding the use of hands-on materials and implementation of the discovery or inquiry approach,
(d) more permanent equipment such as microscopes or balances and better maintenance of equipment.

The videodisc can offer viable solutions to all of those problems. It can include teacher orientation as well as materials for students. It can actually implement interactive discovery or inquiry approaches without the need for special or extensive teacher training. Furthermore, it can visualize and simulate scientific equipment and experiments that schools cannot afford.

(2) The videodisc can add interest, enthusiasm, and motivation now lacking in most science courses. The data in this report bear this out strongly.

(3) Through interactive practice trials with feedback and through realistic practice (rather than such heavy reliance on verbal questions), the interactive videodisc can enable students to learn science in less time, with much less effort, and with increases in interest and enthusiasm. This finding is borne out strongly by the data reported herein.

(4) The motivation, fun, reduced learning effort and increased effectiveness can attract more students into careers in science and technology. The data in this study is not definitive but provides a strong indication that this is indeed the case.

(5) The videodisc can provide teachers with an interactive video text and motion library of information on a particular subject matter area. Difficult and hard to teach concepts (e.g., in biology, respiration, photosynthesis, Krebs cycle, physiology, genetic development, and protein synthesis) could be taught via clearly specified rules, examples, short motion clips, and interactive practice with answer feedback frames. These materials could be used to teach both teachers and students the more difficult science concepts. This is a very rich instructional tool for teachers. A single disc or a small library of videodiscs could largely free the teacher from dependence on the single dominant textbook. Initially, videodisc can

be used by teachers in classrooms, or by small groups of students. Later, when systems are more widely available, increasing numbers of students could have hands-on experiences with interactive videodisc systems to provide the individualized trials and feedback they need.

(6) The equipment simulations in this study showed that it is possible to teach conceptually the use of expensive laboratory equipment. Some of the experience reported herein suggests that equipment simulations for teaching use of expensive or hard-to-obtain equipment can have a significant impact on some of the problems mentioned in the public education, industrial, and military sectors. The same is true for the problem of equipment maintenance which is so critical in the industrial and military sectors. Videodisc simulations and job aids can improve maintenance substantially.

In summary, while a national commitment is needed to solve the first problem mentioned in the section on national needs, the interactive videodisc can have a significant impact on all of the other problems. It can help break science teaching out of its dull and difficult delivery via verbal abstractions. It can lead to greatly increased motivation and interest, due both to teaching science more effectively and quickly for masses of students, and to the fun, visual simulations, games, and intrinsic appeal of the video images. It can, via simulation, provide for enormous enrichment to laboratory and field activities, and where no other choice exists, represents a far more effective substitute for laboratory learning than textbooks and verbalizations. In doing all of this, it can increase enrollments in science and engineering, and help reverse the growing technological illiteracy of our populous.

RESEARCH AND DEVELOPMENT ISSUES

This study addresses six major research and development issues. These constitute the major divisions in the remainder of this report. The issues are as follows:

(I) Hardware configurations. What hardware configurations appear most promising for near future and longer range development?

(II) Software. What software conventions appear most promising for the delivery of interactive videodisc instruction?

(III) Courseware and Instructional Strategies. What was learned from the biology courseware and the different instructional strategies implemented in this project?

(IV) Theoretical Issues. Intelligent videodisc systems offer new possibilities for teaching and learning. In what ways would a comprehensive model of teaching and learning for the new delivery system differ from earlier models?

(V) Evaluation. What are the effects of videodisc instruction compared to conventional methods of college biology instruction?

(1) Are there differences in the relative amount of presentation time and outside study time required for each instructional system?

(2) Are there differences in student achievement and retention for objective and short answer test items for each instructional system?

(3) What are the student and teacher reactions toward videodisc learning?

(4) What are the primary learning strategies of students using the various videodisc learning systems?

(VI) What's Next? What future directions can be recommended on the basis of this research and development project?

Approach Taken in This Paper

In order to keep this final report in bounds, issues I through IV will be touched on lightly. The first three are design-oriented issues about hardware, software, and instructional strategies. The fourth deals with theoretical issues about videodiscs and their role in a comprehensive model of learning and teaching. In the sections that follow, these issues will be highlighted with a broad brush, with references made to other sources. The issues under heading V, Evaluation, will be dealt with thoroughly in this paper. The experimental methodologies used will be explained in Section V. Section VI consists of conclusions the authors have drawn from the project and recommendations for future activities.

I. THE HARDWARE CONFIGURATION ISSUE

Designing, building, evaluating and rebuilding the hardware configuration consumed major resources on this project. When the proposal was written in 1978, the most promising 16-bit microprocessor chip on the market was the Texas Instruments 9900. An initial hardware configuration was built using this chip. This hardware configuration was described in the first semi-annual report. UCSD PASCAL was implemented on this processor and the CDS authoring language implemented in the UCSD PASCAL. Unfortunately, the processing speed of the resulting configuration was too slow to be acceptable.

The WICAT hardware philosophy is that the trends in large scale integration of computer circuits and memories clearly make it advantageous to sacrifice software efficiency for human efficiency in authoring and use. It is unwise to begin serious software development--an extremely costly process--on underpowered microprocessors. Thus at the beginning, the 8-bit microprocessors were rejected and a 16-bit microprocessor was chosen. When the T.I. 9900 implementation of our particular software proved to be too slow (although the 9900 is excellent in many other applications) we moved to a PASCAL Microengine manufactured by Western Digital. Instead of implementing UCSD PASCAL in a pseudo-machine code, (p-code) which must be interpreted for the PASCAL compiler to work, the Microengine implemented UCSD PASCAL p-code directly and sped up processing from seven to ten times over the previous implementation. Although this implementation was generally satisfactory, there were some more complex routines in the eventual program that executed more slowly than desired. Most serious was the limitation of the microengine to addressing 64K of random access memory. As the software grew to accommodate more and more of the delivery system features for this project--software to control the interactive videodisc, software to create line graphics on a black and white screen, software to handle interrupts from the learner control keyboard--there was a decrease in the amount of space available for the lessons. The result was that at the end the computer had to go to disc to fetch lesson material after almost every student input, introducing unsatisfactory delays due to searching the floppy disks.

After the evaluation studies reported herein were completed, the program was transferred to a new microprocessor system developed by WICAT Systems, Inc. based on the Motorola 68000 chip. This is an extremely fast microprocessor operating at 8 MHz. It can address 16 megabytes of main memory using a 24-bit address bus. The minimum configuration of this small work station is 256K bytes of main memory. As the software is reconfigured to take advantage of the speed and memory on this processor, the delays due to processing speed and disk access will be reduced.

A second major problem in hardware was with the videodisc player. In the proposal, it was decided to interface the Magnavox consumer model player, because of its lower price and wider availability (at that time). As the project developed, the DiscoVision Industrial/Educational player became well established and proved itself in terms of reliability and speed of access. The implementation of the Magnavox player proved to be unsatisfactory because of the unreliability of the player; it was not built to withstand the rapid and frequent random accessing under computer control. In addition, the search time on the consumer model player is considerably slower than on the more expensive Industrial/Educational players. The change to the DiscoVision player required additional engineering and software effort.

A third major component was the videodisc interface board. This circuit board makes it possible to interface any optical videodisc player, whether DiscoVision, Magnavox, Sony or Pioneer, to an external computer. Not only was a two-way interface desired so that the frame number could be read by the computer as well as commands sent to the player, but overlay capability was desired. This capability enables the author to specify computer generated text or graphics to be overlayed on any given position of a video frame. The Texas Instruments 9918 video display processor was used in this implementation. It was initially unsatisfactory due to jitter and picture tear on the overlay. But these problems have since been largely overcome so that the interface board has proved to be satisfactory.

The hardware configuration using the microengine is depicted in Figure 1. On the top of the desk are two monitors, the left one (color) is used to present the videodisc displays and the right one presents monochromatic computer text and graphics. The keyboard is detachable and has a special learner control command set of 16 keys at the right. The PASCAL Microengine is placed under the table beneath the keyboard. The two floppy disk drives housed with the Microengine are clearly visible. A drawer containing the videodisc player is open to show the earlier player, a consumer model Magnavox player. Not shown in the picture is the videodisc interface board. This circuit board interfaces between the keyboard, the videodisc player, and the color television monitor. Under computer control it activates any of the player mode functions (play, forward, or reverse, search, still frame, or slow motion). The student can control all of these keys with a set of special control keys at the right of the keyboard. Videodisc control may be restricted within a particular domain of the videodisc, that is, between two frame addresses. The computer can mix a computer-generated signal with the video signal coming into the interface box from the videodisc player. This composite signal can be displayed on a television monitor.

The videodisc interface board is a complicated piece of circuitry. It actually contains two microprocessors, a Texas Instruments 9981 microprocessor and a Texas Instruments 9918 video display processor. An extensive program is

Figure 1

THE PROTOTYPE INTELLIGENT VIDEODISC SYSTEM

executed in the 9981, consisting of some 16K bytes of assembly language program stored on ROM chips within the videodisc interface board. This makes it convenient for an external computer to send English-like instructions to the interface board and have those instructions translated into controls to generate text and graphics, or to activate the videodisc player in a particular way.

The Two-Screen Issue. A major issue in this project was the use of two screens instead of one. There were two reasons for the decision to experiment with two screens. One was that a color television screen does not provide for medium or high resolution graphics; whereas a black and white computer display could provide this higher resolution. Another reason was our desire to experiment with the use of status information and orientation information on the second screen to help the student.

The study did not provide a clear answer to the one-screen vs. two-screen issue in the long run. However, in the short run, due to interaction with the speed of generating the display on the computer screen, one screen appears to be better than two. It is simpler, less expensive, and less confusing. Also, the slow speed due to disk access previously mentioned highlighted the status and orientation information on the computer screen too much so that it served as a distraction rather than a convenient aid that could be attended to quickly by a student whose major focus was on the instructional information coming primarily from the color monitor.

II. SOFTWARE

By software, we mean the generalized computer programs designed to deliver any of a variety of instructional strategies an author may select or design. Also, software is required to author such strategies. Software is distinguished from courseware, the latter referring to the content materials of biology implemented within the strategies made possible by the software and hardware.

The authoring software used in this project was the CDS system (Courseware Design System) developed and distributed by WICAT Systems, Inc. Documentation on the CDS system and how it may be used to facilitate authoring is available from WICAT Systems.[1]

[1]WICAT Systems, Inc. 1160 South State #10, Orem, Utah 84057

The authoring system and the student registration package were developed independently of any government-financed project. The way this software was used, and the programs written within it are of interest in this report. These can best be discussed in relationship to the special keyboard which is depicted in Figure 2 on the next page.

Figure 2 shows a cut of a portion of a regular typewriter keyboard at the left and 16 special learner control keys at the right. The programs authored in CDS allow the use of both keyboards. The typewriter keyboard is used for entering registration information, consisting of alphanumeric data. This data is captured in the registration and student management files and used by the program to identify the student and teacher at later logons, and to keep records according to each student's name and I.D. Reports can be generated across students using the registration and record generation software.

The typewriter keyboard is also used by the student in entering answers to constructed response questions by typing words or phrases on the keyboard, followed by the return key. Multiple choice questions use the numbers or letters as well.

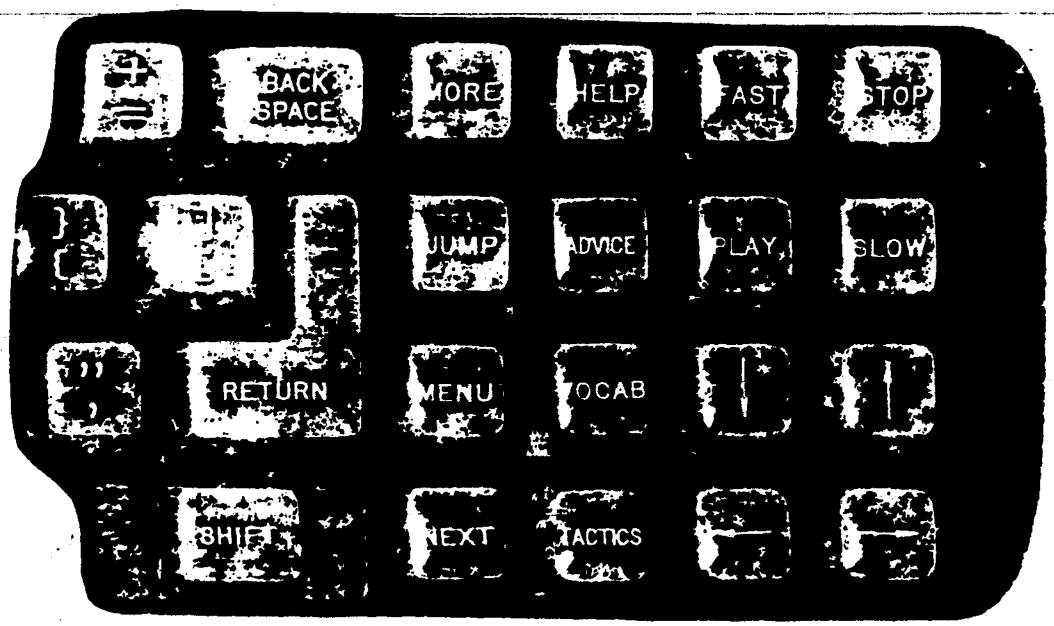
Answers to questions are sometimes entered by using the cursor control arrows in the right corner of the keyboard. These enable marking responses to be entered by moving the cursor to a particular location on the screen.

The 16 key learner control keyboard can be divided conceptually into several groups: videodisc control keys, sequence control keys, and strategy/tactics keys..

Videodisc Control Keys. The eight keys at the far right are the videodisc control keys. The play key initiates a motion sequence and the student can alter the motion sequence by using fast, slow, or stop. Once the stop key has been pressed the student can go frame by frame forwards or backwards using the two horizontal arrows. An important feature of videodisc control is the "domain control" feature of the software. In an intelligent videodisc program, there are two separate data bases to be coordinated, the data base of visual and auditory information on the videodisc and the data base of computer programs with branching, answer processing, etc., on the computer. If the student had complete control of the videodisc, the two programs could get out of synchronization very easily. Thus, the author is allowed to specify a domain by indicating a lower and higher frame number between which the videodisc control keys will operate. A domain might be a motion segment, or it might be a sequence

Figure 2.

Intelligent Videodisc Keyboard



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of still frames on the videodisc. When the student reaches the frame number at either end of a specified domain, the computer program takes over again and gives the student choices which keep disc and program in synchronization. Domain control requires special software features based on a videodisc interface that constantly has the frame number currently being played on the disc available to the computer program.

Sequence Control Keys. In addition to control of sequence on the videodisc, the next, menu, and jump keys enable the student to control his location within the course in a powerful manner. The student can always press the next key if he does not know what to do and a default path through the course will be followed by the computer program. Alternately, the student can move to a higher level of the course by pressing the menu key. If the student is working on an instructional segment, he will see a lesson menu that shows all of the lesson sequences, still frame sequences, practice sequences, etc. in that lesson, and lables them by subheadings. Pressing the menu key a second time will jump the student to a unit menu indicating the contents of one of the four units. A third depression will take the student to the course menu, which provides the overall course options.

The student is equipped with a Table of Contents that gives the alphanumeric identifiers of each unit, lesson, and lesson segment. A student can jump to any of these identifiers directly, without pressing menu several times then coming down through the units and lessons to the desired section. The jump command allows the student to type in a segment designator and jump right to it. For example, if in response to the computer prompt after pressing the jump key, the learner types in 1.2.a (which designates Segment a of lesson 2 of Unit 1). The student's current location will be recorded and the learner will be jumped to a new section. He can return to the previous location by using jump a second time.

Strategy and Tactics Keys. These keys are tactics, vocab, more, help, and advice. The advice key is a descendant of the TICCIT[2] advisor that gives general status information about what the student has accomplished and provides generalized comments on strategies and tactics. The CDS software is set up to allow authors to program this information according to any kind of algorithm the author may desire. But in this project little was done with the advisor because the project was too short to evaluate it.

[2]TICCIT was a large CAI project that pioneered learner control.

When the student presses the tactics key, he is treated to a menu of options in some ways reminiscent of the TICCIT project, but updated to the videodisc medium. The student's choices on the tactics menu include rule which lets him review all of the rules in the lesson or unit, motion which allows him to go through any of the motion sequences, micrographs which allows him to review the micrograph file for that lesson or unit, and practice which takes the student directly to the practice problems and lets him move through them in sequence. In essence, the tactics key allows the students to put together different tactics for attacking a lesson.

The vocab key takes the student to the interactive glossary. Here, after selecting the term to be defined, the student receives a terse definition of the term and then can press the next button for additional pages of extended definitions and graphic illustrations.

The more key provides more sophisticated and advanced information about a given subject. The more key functions at different points during the course (the student is told when it is functional). The more key is active when a research article or some historical or technical optional information is available for student view. The more key was designed to attract students with higher levels of role commitment to more advanced study.

Because not every lesson item had all of the options with it, a special display was provided. The student could tell when the keys were functional by looking at the computer screen. The software presented a 4x4 grid showing which keys were functional at any given time. In addition, the computer screen showed a status display for the current lesson the student was in, showing what parts had been completed, what parts had been partially worked, and what parts had not yet been looked at.

A status display and the grid indicating active keys were designed to be unobtrusive and to be ignored by the student except when a glance was needed. However, the speed of floppy disk accessing and processing in the microengine was so slow that this feature became overly obtrusive and was annoying to the students, as indicated by the affective data presented later in this report.

Summary

By way of evaluation of the software features, the videodisc control features were quite popular and easy to use as were the next and tactics keys. Menu and jump were relatively easy to use and understand. The vocab key and its options were not used frequently enough to judge the usefulness of this feature. The students were under time pressure in the tightly controlled studies of unit 2. Thus, the vocabulary feature, and the access to the related vocabulary games, were not adequately assessed during the course of this project. The advisor and the orientation information on the computer screen need additional work to be made more useful and less obtrusive.

III. A DESCRIPTION OF THE COURSEWARE AND INSTRUCTIONAL STRATEGIES

Table I on the next page is a table of contents for the interactive videodisc. It consists of four major units of instruction: an introduction, a unit on the cellular and molecular basis of development, a unit on the genetic basis for protein synthesis, and a unit on genetic control of development. Unit zero explains to the naive user the features of the intelligent videodisc system and how to control them in his or her own way. This unit also discusses different instructional strategies students might want to use, depending upon the role each student selects as a learner. This role selection discussion helps the student decide whether he is:

a) a student desiring to get through as quickly as possible and with the least work,

b) a student who would like to learn enough to continue later as an informed lay person, who can read about and understand new developments in biology,

c) a person who will use biological science as an adjunct or secondary discipline in a career,

d) a student who would like to become a biological scientist and contribute to the kind of knowledge presented on this disc.

Each of these levels of role commitment to biology has an associated learning strategy for using the intelligent videodisc system. The strategies were explained in Unit 0.

Units 1, 2, and 3 utilize a rule-example-practice form of instructional strategy--a descendant of the instructional strategy pioneered on the TICCIT project, an NSF-sponsored computer-assisted instruction project of the early 1970's.

Table I

Table of Contents	Videodisc Frame Number
Credits	
	SIDE A
UNIT 0 Introduction	00001
0.1 Motion Menu Introduction	00009
0.2 How to Use This Intelligent Videodisc System	23786
0.2c Learning with This Videodisc and Your Role as a Learner	25497
UNIT 1 The Cellular and Molecular Basis of Development	27205
1.1 The Basic Model of Development	27207
1.2 Cell Structure and Function	35177
1.3 The Central Role of Proteins	43505
(a) How Cells Differ	43514
(b) The Nature of Protein Molecules	43560
(c) Structural Organization of Proteins	43601
(d) Enzymes and Isozymes	45146
Lab: Electropheresis	45187
Vocabulary Games	45449
Glossary	45505
Micrograph File	45887
Scientific Notation	46012
	SIDE B
UNIT 2 The Genetic Basis for Protein Synthesis	00001
2.1 Genetic Structures	00005
2.2 Protein Synthesis: Phase I, Transcription	02711
2.3 Protein Synthesis: Phase II, Translation	03927
2.4 More About RNA and Protein Synthesis	06285
Experimental Techniques and Evidence	
(a) Experimental Techniques and Interpreting Results	06292
(b) Lab Guides	06493
(c) Experimental Evidence Relating to the Synthesis and Function of RNA	06573
UNIT 3 Genetic Control of Differentiation and Development	06722
3.1 Two Models for Genetic Control	06727
3.2 Cleavage: The Egg in Control	10887
3.3 Gastrulation: Cells Move and Begin to Interact	16813
3.4 The Mystery of Organogenesis	23921
3.5 The Development Process	24955

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Rather than selecting rules, examples, etc. item by item as with TICCIT, the student is lead through a sequence of still frames similar to a book or filmstrip. Most of these were discussion frames (blue background) which carried the main thought, but the discussion frames were interspersed with rust-colored rule frames, pictorial or black background example frames, green-colored practice frames, and gray-colored answer frames which followed each practice frame. In addition, from time to time the author inserted yellow comment frames to advise the student of where he was, what was coming next, what some options were, etc. Content frames, also yellow, provided orientation regarding the units and lessons the student was entering. A more detailed content display for each lesson, providing status information regarding what the student had already seen, was presented on the computer screen at all times.

As discussed in the software section, the student had many options for accessing the materials in unique ways. The student could jump at any time to the next higher menu for the lesson, unit, or for the entire course. The student could then access other parts of the course by ascending down through the levels of menus. The student could jump directly to any of the lessons or units using the jump key and the numerical identifier of the lesson or segment.

Using the tactics key, the student could select out the rules, the motion sequences, or the micrographs from any lesson or unit and look at them separately. Also the student could jump directly into the practice problems using the tactics key. The vocabulary key provided access to the interactive glossary in which the student could get definitions, helps, and in some cases, micrographs or other graphic displays.

Special features were added to the videodisc in addition to the major presentation of lessons in a learner controlled rule-example-practice format. Various laboratory exercises and lab guides were implemented on each side of the disc, the most extensive being a simulated laboratory in electrophoresis. There are three different kinds of vocabulary games by which the student could learn to become fascile in the use of the extensive biology terminology introduced on the disc. The student could take a few short lessons to teach him scientific notation. The student could have an overview and lab-guides (illustrated walk-through of procedure) to teach him the use of various kinds of lab equipment, including the centrifuge, the scintillation counter, and the gas chromatograph.

All in all, the courseware provided a rich and varied selection. It was designed to intrigue and invite the student to go more deeply and to investigate experimental methods or advanced discussions available easily on the disc, but not required. The national problems addressed at the beginning of this report were salient in the minds of the courseware designers. We wanted something that would be appealing and inviting and would lead students into higher and higher levels of role commitment in biology, and to higher and higher levels of understanding and sophistication. The evaluation, however, was not able to determine the extent to which students will voluntarily explore these optional materials. The evaluation was instead, focused on time, effectiveness, and affective data relative to one unit, Unit 2, which is a difficult unit of instruction for most biology students. The additional materials provide a demonstration of what is possible, and were stimulated in part by an evolving model of learning and teaching appropriate to this delivery system.

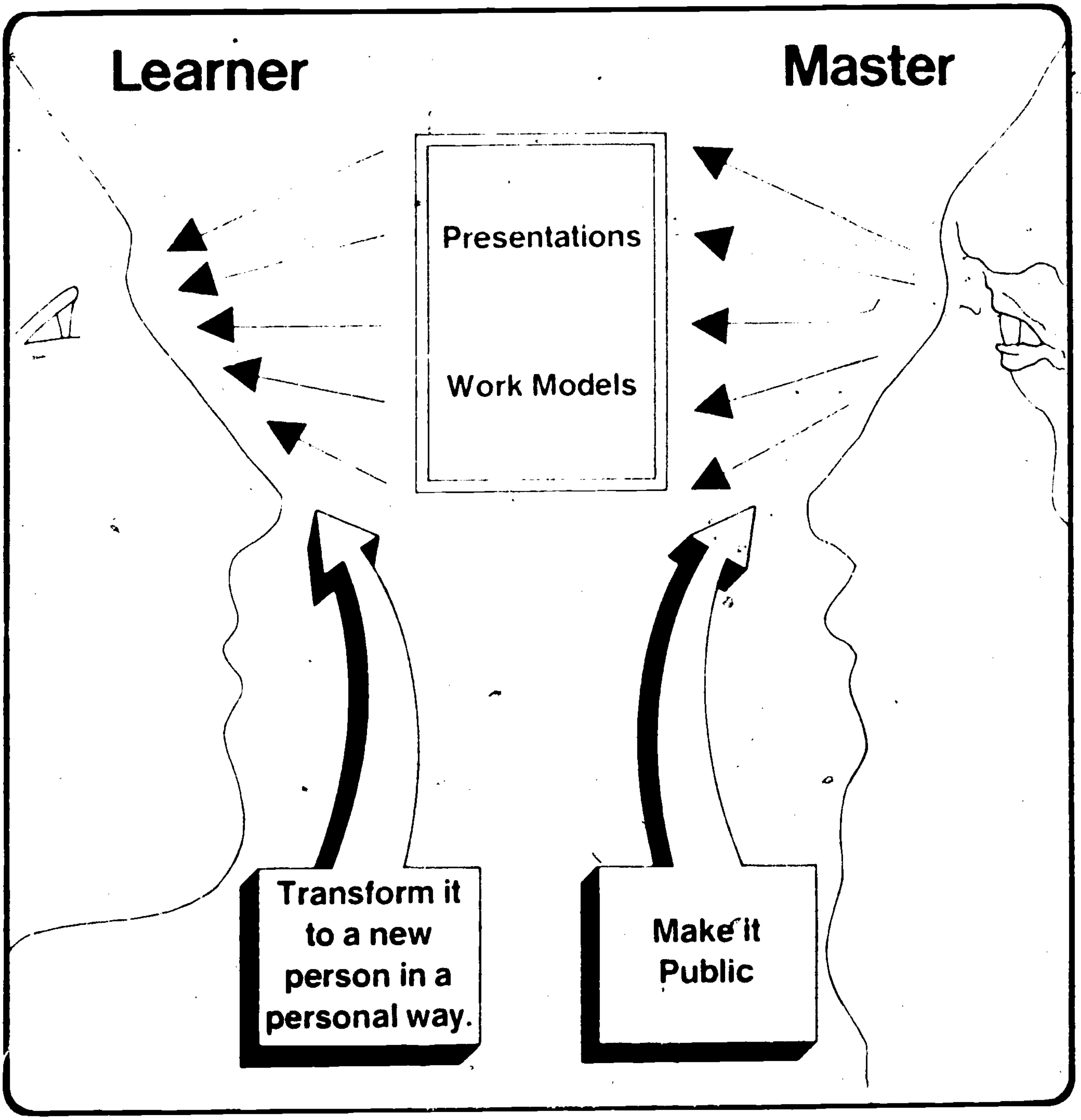
IV. SOME LEARNING AND TEACHING ISSUES

A comprehensive model of learning and teaching is under development at WICAT, stimulated by work on this and other intelligent videodisc research and development projects, and by a series of projects conducted under the auspices of the General Electric Management Development Institute in Crotonville, New York. (See Bunderson and Olsen, 1980; Bunderson, 1981).

A number of important influences on the design of the courseware came from a consideration of the nature of personal mastery. Personal mastery is seen to be the goal of planned learning and teaching; that is, the goal of learning is to become like a real or possible person, not to become like a book--an encyclopedia of facts--like a computer information storage and retrieval system, or any other non-human entity. Figure 3 is a copy of a transparency used to illustrate some key aspects of the nature of teaching and learning. Materials development for teaching requires the identification of individuals who are masters in the subject area to be taught. Different aspects of the master's personal knowledge must be made public in visible forms in order to be presented to students. Aspects of mastery are made publicly visible through presentations (auditory, visual, textual, or 3-dimensional forms), and work models (situations to practice in that model the work the master performs day to day). The term "work model" is a generic term for simulation. A materials development and instructional planning process is needed to create the presentations and work models and to organize and sequence them into instructional programs.

FIGURE 3

Basic Metaphor of Learning for Personal Mastery



The learning process depicted in Figure 3 shows the learner extracting from the presentations and work models personal learning appropriate to the learner's own unique attributes and commitments. As mentioned in the last section, there were four levels of role commitment identified for personal mastery in biology: becoming an informed lay person in biology, using biology as a sub-technical discipline, or becoming a biological scientist. Another level of role commitment, called "practical learner" (finishing the courses as quickly as possible and with minimum effort required for an acceptable grade), was also identified. The problems of scientific and technological illiteracy discussed in the section on national needs require higher levels of role commitment from students exposed to science, and require more students and lay people to learn of science. To achieve this, more learners must shift their role commitment into one of the three higher categories.

In making the personal mastery of biological scientists, technicians, and informed lay persons visible for teaching and learning to occur, it is desirable to identify three major categories of information to be made public. These are:

Knowledge
- Conversational
- Procedural
- Causal

Role Commitment
- Purposes and Values
- Role Metaphors

Personal Profile
- Aptitudes and Habits
- Concepts About Self
- Personal Traits
- Learning Strategies

The personal knowledge required by the informed lay person (and, as the basics for future technicians and biological scientists) can be broken down into three categories: conversational knowledge, procedural knowledge, and causal knowledge. Conversational knowledge here includes the memorization of terms, the recognition of relationships between terms, the classification of unencountered instances of a concept named by some term, and the recognition of when a particular principle named by some term applies in an unencountered situation. Conversational knowledge is a major element in learning biology because there is so much new terminology to be identified and then attached to the proper concepts. This category led to the design of the interactive glossary and the three conversational games.

The interactive glossary contains terse definitions of each of the new terms. Special attention was paid to terms introduced on the disc, with particular attention to any terms utilized in the "rule" frames. In addition to the terse definitions, expanded definitions which elaborated on the concepts and, in some cases, provided historical or anecdotal color, were included. Where application of principles was involved in the term, the procedure was spelled out in the expanded definitions. An effort was made to incorporate micrographs and other graphics to help students who learn visually as well as through words. The conversational games help the students develop associations between various terms and learn how terms can be hierarchically and relationally organized. In addition, the conversational games were designed to stimulate the proper use of the terminology in writing and in talking.

Finally, the students must have some indication of importance or priority in learning concepts and principles denoted by terms. This function was accomplished through the use of the rust-colored rule frames, which highlighted in a succinct fashion the statements which were important for the students to understand and remember.

Procedural knowledge deals with the ability and skill to follow some formal procedure. Examples are the procedure for running a centrifuge or setting up an electrophoresis experiment, or the procedure for classifying an unencountered organism using a biological key (a binary decision tree).

Causal knowledge goes beyond memorizing vocabulary, relationships, or classifying unencountered instances and situations. It goes beyond skillful use of procedures. Causal knowledge involves the application of two or more principles in making a prediction or in making a diagnosis. That is, the students might be given a novel experiment design and asked to predict a probable result based on the principles they had learned. This would exercise and test causal knowledge. Alternately, the students might be given a set of symptoms existing in some organism and asked to diagnose the probable cause, requiring them to work back through some learned principles to a probable cause. In a diagnostic exercise, the student would be given the opportunity to request additional information to help isolate the cause. Causal knowledge represents a higher level of mastery sought by science teachers the world over for their students.

Role commitment has been mentioned earlier. It helps the student identify his level of aspiration to continue the quest of biological understanding, and to contrast his level with other possible levels of commitment. The degree of role commitment is of course highly related to the extent to which the student will achieve higher levels of procedural and causal knowledge through the lessons on this disc, and more importantly, the extent to which the learner will continue to expand his knowledge after leaving this experience behind.

Four levels of role commitment are identified in Unit 0 of the disc and were assessed in interviews and through questionnaires. A pre-questionnaire was given to the students at both Dallas and Brigham Young University and the following percentages of students showed each level of role commitment. (Note: these students were drawn from classes of non-biology majors taking biology as a required course).

Table II

ROLE COMMITMENTS OF NON-BIOLOGY MAJORS
PRIOR TO VIDEODISC LEARNING EXPERIENCE

Selected Role	% Choosing
Practical Learner	46.4
Informed Lay Person	27.8
Future Specialist	20.6
Biological Scientist	2.1

The third area of personal knowledge of the master is the personal profile of his abilities, traits, and strategies. This category of the knowledge of masters is simply a way of reminding us that every person is unique. Mastery at any of the levels of commitment toward continued learning can be enhanced by the profile of abilities and learning strategies of each student, but each student will necessarily be unique. This is an important criterion in designing an intelligent videodisc system, because the system should be applicable for students with as many different profiles as possible. Furthermore, learning strategies can be improved. Thus, an important consideration in this research project was to identify the different strategies used by students, and provide suggestions for different strategies. Unit 0 presented the authors' suggestions for how different learning strategies would be related to the different levels of role commitment.

The design of this disc includes many features and possibilities that could not be fully evaluated during the course of this 22-month project. It would be desirable to investigate fully the extensive learner control features, the attempt to encourage better individualized learning strategies, and the efforts to teach conversational, procedural, and causal knowledge. It would be desirable to investigate more fully changes in role commitment, and the extent to which learners would be (given more time) attracted into the optional portions of the disc because of the intrinsically motivating nature of the options. These investigations require research studies much more extensive and longitudinal than those we were able to conduct after the system was complete. This kind of longitudinal research is needed to obtain definitive answers to the questions of national need. How well can students be attracted into scientific careers and how can involvement be sustained after the initial use of rich, interactive videodisc learning systems?

The comprehensive model of learning and teaching has a number of other attributes of relevance to the issue of evaluating intelligent videodisc systems. A central concept in the model is the notion of work models, defined above as a generic name for simulations. One of the problems discussed in the introductory section was that science education is now largely taught through verbal abstractions, presented in textbooks and through vocalizations by teachers. The ability to present simulations, lab guides, animations, and visualizations of hard-to-imagine processes is a most significant advantage made possible by the videodisc. In particular, while books and movies can replicate presentations, only computers associated with videodiscs can conveniently and cost effectively replicate a wide range of work models. This has been a problem in teacher education because most teachers are not equpped either with the equipment or the skills to guide students through complex laboratory exercises or simulations involving complex procedural and causal knowledge. Thus, teachers generally stay at the conversational knowledge level.

Another aspect of the new technologies which is of great importance is the possibility of setting up on-the-job teaching delivery systems. We call this a "future assurance" network. In military and industrial training this is most significant because it allows employees to receive continued education after they have left the formal education settings and have gone out onto the job. Since the videodisc can replicate both presentations and work models effectively, it is a very promising tool for the establishment of future assurance networks. In addition to intelligent videodiscs, network communications are needed so that the headquarters of industry, military, and extension education organizations can obtain data back from the learning that occurs in the field. This concept calls for a distributed network of videodisc systems and data bases.

There are numerous implications of intelligent videodisc systems for materials development and other teaching support processes. Some of these are outlined in Bunderson and Campbell (1980), and in Campbell and Bunderson (1981).

V. EFFECTS OF VIDEODISC INSTRUCTION COMPARED TO CONVENTIONAL INSTRUCTION

This section contains the methodology and results of the Phase III evaluation of intelligent videodisc systems. Taken together with the evaluation of the Phase I and II systems, this body of data probably represents the most extensive evaluation to date of videodisc systems in science education. The three phases were as follows:

Phase I - Use of the manual videodisc in biology instruction with both university and community college students. Analysis of features, strategies, and effectiveness.

Phase II - Control of the manual videodisc by a microprocessor. Addition of answer-processing and feedback (including constructed answers), menus, branching, scoring.

Phase III - Evaluation of a new disc designed for the intelligent videodisc concepts. More extensive learner control features for accessing the data base on the videodisc in a variety of ways, more extensive answer processing, simulation, vocabulary games, interactive glossary, lab procedure guides, etc.

METHODS

The Treatment Groups

Course and Instructor Selection. The introductory biology courses at Brigham Young University and Brookhaven Community College were reviewed to identify the courses which were most comparable in terms of student population characteristics, instructional content coverage and teaching methods. Student rating information, departmental chairman recommendations and classroom observations were employed to select the best instructors for the classroom lecture groups. All three sources confirmed the selection of the three classroom instructors as the best instructors for each course.

Description of Research Populations. For Phase III, four college classes taught by the top instructors were selected for the research studies; three classes were from Introductory Biology 100 courses at Brigham Young University and the fourth course was from an Introductory Biology 100 course at Brookhaven College. The research studies were conducted in three phases. Phase I involved a study of the presentation features, learning time, student achievement and student reactions of the manual videodisc. Twenty-four students were selected from a Biology 100 class at BYU for participation in the Phase I manual videodisc study. Phase II of the research concerned student learning time, achievement attitudes for a computer enhanced version of the manual videodisc. The computer enhancements included the following: interactive practice and feedback sequences, student status information on performance scores and menu-selection of alternative learning and review tactics.

Research Design Considerations

A comparative evaluation design was employed for Phase II between the computer enhanced videodisc and a high quality classroom lecture. Twenty-five volunteer students from an Introductory Biology course were selected for participation in the computer enhanced videodisc. The remaining students in the class constituted the classroom lecture group. The researchers would have preferred to randomize students into treatment groups; however, during the initiation of the study the teacher requested a list of student volunteers. Following this action the researchers felt it was best to continue the research with a volunteer population. Information was collected on a pre-treatment questionnaire which allowed the testing of pre-treatment equivalence between groups.

For Phase III a comparative evaluation design was also followed. Two sections of Introductory Biology were selected for participation, one section from BYU and one section from

Brookhaven Community College. The students were then randomly assigned to the two videodisc (BYU N=19; BCC N=28)groups and the two classroom lecture groups (the remaining students in each of the two courses).

The students in all videodisc groups were asked not to attend class on the days the instructor would be covering the selected content materials. They were told that they would receive their instruction according to the specified videodisc treatment group.

Content Selection. A common instructional unit on DNA structure and function and the transcription and translation phases of protein synthesis was selected for the comparative evaluations. This unit was selected because of the common overlap between the content and objectives of the videodisc instructional unit, the classroom lecture topics, the class syllabus and the assigned textbooks for the course. Table III presents a list of the content topics selected for the studies. Each classroom instructor was given a list of the target learning objectives and the achievement test for review at least one day prior to the scheduled classroom instructional period.

Experimental Design. A pre-post-retention experimental design was selected for both the Phase II and the Phase III studies (Campbell and Stanley, 1977). The research design is illustrated in Table IV. Students in the three lecture and four videodisc groups received a pre-questionnaire, a pretest, the designated treatment, a posttest (one day after instruction) and a retention test (one week after the post test). The same test was used for the pretest, posttest, and retention test. A post questionnaire concerning student reactions and ratings was given to the videodisc groups.

The prequestionnaire requested information on student age, sex, class standing, high school and college GPA, college major, and pre-treatment levels of interest, knowledge, confidence, and attention in biology and attention in their college major courses. Students were also asked to indicate which of the following four role commitment classifications best described themselves: a practical learner, an interested lay person, a future specialist or a research scientist.

Procedures. The students in the three classroom lecture groups received their instruction on the selected unit via the regular classroom lectures. The students in the four videodisc groups were asked not to attend the classroom lecture on the day the selected unit was scheduled, but were told that they would receive the same instruction by the computer videodisc.

Table IV

Pre-Questionnaire	0_{Q1}	0_{Q1}	
Pre-Test	0_{T1}	0_{T1}	T
Treatment	X_1	X_2	I
Post-Questionnaire	0_{Q2}		M
Post-Test (one day)	0_{T2}	0_{T2}	E
Retention Test	0_{T3}	0_{T3}	

Legend

X_1 = Computer Videodisc

X_2 = Classroom Lecture

0 = Observation or Measurement

Q_1 = Pre-Questionnaire

Q_2 = Post-Questionnaire

T_1 = Pre-Test

T_2 = Post-Test

T_3 = Retention Test

TABLE III
Content Coverage Comparisons

Videodisc	Class Lecture Notes	Textbook
DNA	DNA	DNA
Chromosomes	Chromosomes	Chromosomes
Deoxyribose Sugar	Deoxyribose Sugar	Deoxyribose Sugar
Phosphate	Phosphate	*
Thymine	Thymine	Thymine
Adenine	Adenine	Adenine
Cytosine	Cytosine	Cytosine
Guanine	Guanine	Guanine
Double Helix	Double Helix	Double Helix
DNA Replication	DNA Replication	DNA Replication
Nucleotides	Nucleotides	Nucleotides
RNA	RNA	RNA
Uracil	Uracil	Uracil
Sugar different	Sugar different	Ribose
Single stranded	Single stranded	Single stranded
m-RNA	m-RNA	m-RNA
t-RNA	t-RNA	t-RNA
r-RNA	r-RNA	r-RNA
Triplet Code	Triplet code	Triplet code
DNA-RNA comparison	DNA-RNA comparison	DNA-RNA comparison
Protein Synthesis	Protein Synthesis	Protein Synthesis
Transcription Steps	Transcription Steps	Transcription Steps
Translation Steps	Translation Steps	Translation Steps
RNA polymerase	*	RNA polymerase
Ribosome	Ribosome	Ribosome

*Topics not common in all three sources

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Classroom observations were conducted during the classroom lecture units. The observers noted the content coverage, the instructional presentation characteristics, the number of practice items presented and questions from the class. The observers also recorded the total presentation time for the classroom lectures.

Students in the videodisc groups were given an introduction to the videodisc system and each of the videodisc control keys. Students were then given a free play period of fifteen minutes to try out each of the videodisc control keys. For Phase II and III the videodisc control keys which were available and their functions are presented in Table V. During the videodisc introduction and free play period, the students were restricted from accessing the selected unit for the comparative study. After completion of the free play period, the students were asked to start the experimental instruction unit.

As students worked through the instruction they were asked to report aloud their use of the videodisc control keys to depart from the normal lesson flow (slow motion, reverse, jump, rule review, etc.) and their reasons for use of the keys. An observer recorded the videodisc keys and the student reasons. The observers also recorded the presentation time for the videodisc instructional unit.

Follow-up interviews were conducted with students who had participated in the videodisc groups and with the classroom instructors.

Detailed Description of Treatment Groups

Description of Presentation Characteristics for the Phase II Classroom Lecture. The Phase II classroom instructor had a well organized presentation using a series of overhead transparencies from the student study guide for the course. These study guide pages were reproduced in text outline form. They also included several line drawing illustrations of the content topics. The instructor elaborated on the study guide pages through the use of analogies and metaphors (e.g., master blueprint=DNA, working blueprint=RNA). In a one hour class the instructor asked 32 practice items and answered 15 questions from the class. The following components combined to make the lecture a quality learning experience: the integrated use of visual illustrations and text explanations, the use of analogies, the large number of practice questions and the answers to student questions.

Table V

Videodisc Learner Control Keys and Functions

Key	Function
Fast	Fast Forward
Slow	Slow Motion
Stop	Stop Motion Sequences
Play	Play Motion Sequences
←	Review back previous frames
→	Preview forward next frames
<	Jump to beginning of Motion Sequence
>	Jump to end of Motion Sequence
Jump	Jump from one place in still frame instruction to another
Tactics	Push to choose Motion Review, Rule Review, Practice Review
Advice	Status Information on Cumulative Practice Scores

Description of Presentation Characteristics of the Phase I Manual Videodisc and Phase II Computer Enhanced Videodisc System. The videodisc provides for integrated use of motion, still frame visuals, and still frame text explanations. The videodisc was designed to provide motion sequences, unit and section outlines, rules, examples, practice items, answer frames and discussion frames.

The computer enhancements to the videodisc include computer control for all videodisc actions (slow motion, reverse, etc.), interactive practice and feedback items, computer place marking for jumping from one section of the lesson to another and a variety of learning and review tactics (motion review, rule review, practice review, etc.). The videodisc unit includes four motion sequences, 21 rule frames, 19 example frames, 43 practice frames and 43 answer frames.

Presentation Characteristics for the Phase III BYU Classroom Lecture. The first Phase III instructor had originally planned to take two lecture days (two fifty minute periods) on the selected content areas. The instructor's lectures were fairly well organized. The instructor provided students with handouts covering nineteen objectives for the designated instructional period. The instructor used overhead transparencies and blackboard illustrations to support his points. The same textbook was used as for the Phase II samples discussed previously. The instructor averaged 5 to 9 practice items per class hour and answered an average of 14 questions from class members. The teacher reviewed well each of the major topics presented in the test. The objectives, visual overheads and answers to student questions combined to make the class very instructive. Following each class period 8 to 12 students would stay for 10 to 15 minutes to ask questions of the instructor. The questions discussed after class were rather intellectually challenging rather than simplistic questions. The instructor notified the students that the test would count as a regular test toward their grade. Thus, the students were highly motivated to learn the content materials.

Presentation Characteristics of the Phase III Dallas Classroom Lecture. The method of classroom instruction used by the biology instructor at Brookhaven Community College was a lecture accompanied by key words and graphics written on overhead transparencies. The instructor began class with a blank transparency and pens of various colors. As he lectured he would write down key words indicating relationships with other keywords by means of arrows, boxes, etc. He would also draw graphic representations of the different concepts or processes using different colors to show contrast between the various elements of the subject under consideration. This method seemed to be very effective in explaining the complex biological relationships involved in this subject.

The class was given several opportunities for practice during the lecture period. The specific practice type was unison class responses for matching the nucleotide bases from a given strand as the instructor pointed to one nucleotide base and then another. Most questions from the class centered around administrative concerns rather than questions about specific lesson content. The students were encouraged to spend time reading their books to learn more completely the material covered in class.

In summary the class was lecture-based with very little class interaction. An overhead projector was used in much the same way as a blackboard would be, for writing words and hand drawn graphic illustrations. It is supposed that the overhead was used because it was more convenient for the teacher and more easily seen by class members.

Videodisc Presentation Characteristics. The presentation time for the Phase III videodisc averaged just over 2 hours during which students saw about 230 still frames. This makes an average of about 30 seconds per frame. Interspersed among these frames were 4 motion sequences with audio accompaniment, each of these lasting about 1 minute. Additional information and feedback were provided on the computer screen (CRT).

Each of the three "lessons" covered were organized in a specific fashion. A lesson began with "overview" frames. Each major concept was introduced with one or more "rule" frames by which it was defined or epitomized.

"Discussion" frames provided examples and further developed the concept. Then students encountered several pairs of "practice" and "feedback" frames. In the entire presentation, students saw 7 "overview" and "objective" frames, 52 "rule" frames, 42 "discussion" and "example" frames, 58 "practice" frames, 57 "feedback" frames, 15 "more" frames and 8 "comment" and "title" frames.

The course was designed to be pleasant to the eye and consistent in its format. "Rule" frames had red background, "discussion" blue, "practice" green, "feedback" grey, etc. Photographs, and drawings helped clarify concepts and make them more interesting.

Students found that the computer screen called them by name and they seemed to enjoy this personal touch as well as the praise they received for a correct response (e.g. "That's corret. You really seem to have a good grasp of the topic.") Wrong choices yielded tactful corrective feedback (e.g. "Not quite right. Recall that...", etc.). Overall scores were presented after each group of practice items.

Students appreciated greatly the capacity to review any frame, motion sequence, or major segment of a lesson. The pointer displayed with the menu on the computer screen allowed students to move off the linear path of the course without becoming lost.

Data Analysis. The classroom observations were summarized to provide descriptive information about the content coverage, presentation characteristics, presentation time and the number of practice items and questions from the class. The videodisc observations were also summarized to provide descriptive information about the content coverage, presentation characteristics, presentation time, videodisc departures from normal lesson flow, and reasons for such departures. The follow-up interviews with students and teachers were also summarized.

The pre and post questionnaires were analyzed using descriptive and inferential statistics for quantitative measures and frequency distributions of open ended comments for the qualitative measures. Chi-Square tests and F-tests were used to test for any pre-treatment differences between groups. Discriptive statistics and F-tests were used to evaluate the presentation time, study time and student achievement comparisons between groups. The major learning strategies in videodisc instruction were summarized from the observer logs.

Description of Achievement Tests. The same test was given as a pre-test, post-test (one day following instruction), and a retention test (one week following the post-test). The test consists of 58 objective items (22 multiple choice items, 27 matching items, and 9 true-false items) and 24 short answer and essay items (22 short answer items and 2 short essay items). The test was designed to be representative of the domain of knowledge presented in the videodisc, in the class syllabus, and in the textbook chapters. The Kuder Richardson KR-20 reliability for the test with each experimental group are presented in Table VI.

Table VI

	PRE	POST	RETENTION	CLASS SUBTEST
Classroom				
Reliability KR-20	.79	.91	.99	.60
Standard Error	3.28	3.00	2.00	1.40
Videodisc				
Reliability KR-20	.74	.87	.99	.60
Standard Error	3.33	2.85	1.83	1.43

Reliabilities of .75 or higher are considered acceptable.

The above data indicate high and very acceptable reliabilities for pre, post and retention tests. The reliability of the tests would be slightly affected by the ipsative nature of one set of four matching items. No other linear dependencies were possible in the data since the other matching items contained either fewer or more response options than test items.

A test key was used for scoring both objective and short answer test items. Blind scoring procedures were used for the short answer items. The blind interrater reliability was .98 to .99 for the short answer questions, and .96 and .99 for the two short essay questions. Seventy percent of the essay scores were identical; 28 percent were within one point; and 2 percent were within two points.

The Phase II classroom instructor also administered a test covering the content of the classroom lectures. A portion of this test, consisting of 19 items (6 multiple choice items, 10 true-false, and 3 matching items), covered similar material as the pre, post, and retention tests. As Table VI indicates, the reliability of the set of items on the class test was considerably lower than the videodisc research test. This is likely due to the smaller number of items (N=19), and the generally less difficult nature of this test (75 percent of the students received a score above 80 percent on this class test).

RESULTS

The results are divided into five sections: (1) Results of the analysis of learning and study time, (2) results of the student achievement analysis, and (3) student and teacher reactions to videodisc learning, and (4) learning strategies with videodisc instruction, and (5) pre-post- changes in knowledge, interest, confidence, and attention.

1. Results of the Time Analysis

The results are summarized in Table VII and Figure 4. For the Phase III Dallas group, the presentation times were 150 minutes for the college classroom and 120 minutes for the intelligent videodisc. The outside study times were 232 minutes for the classroom group and 160 minutes for the videodisc group. The total learning times were 382 minutes for the classroom group and 261 minutes for the videodisc group (31% savings). The total time savings were 121 minutes or 32% in favor of the intelligent videodisc group.

For the Phase III BYU group the presentation times were 150 minutes for the classroom and 138 minutes for the videodisc. The respective outside study times are 265 minutes for the classroom and 101 minutes for the videodisc group (62% savings). The total learning time was 415 minutes for the classroom group and 234 minutes for the intelligent videodisc group. The total time savings was 181 minutes or 41%.

Figure 4 summarizes the time savings comparisons between the videodisc and classroom groups.

Table VII

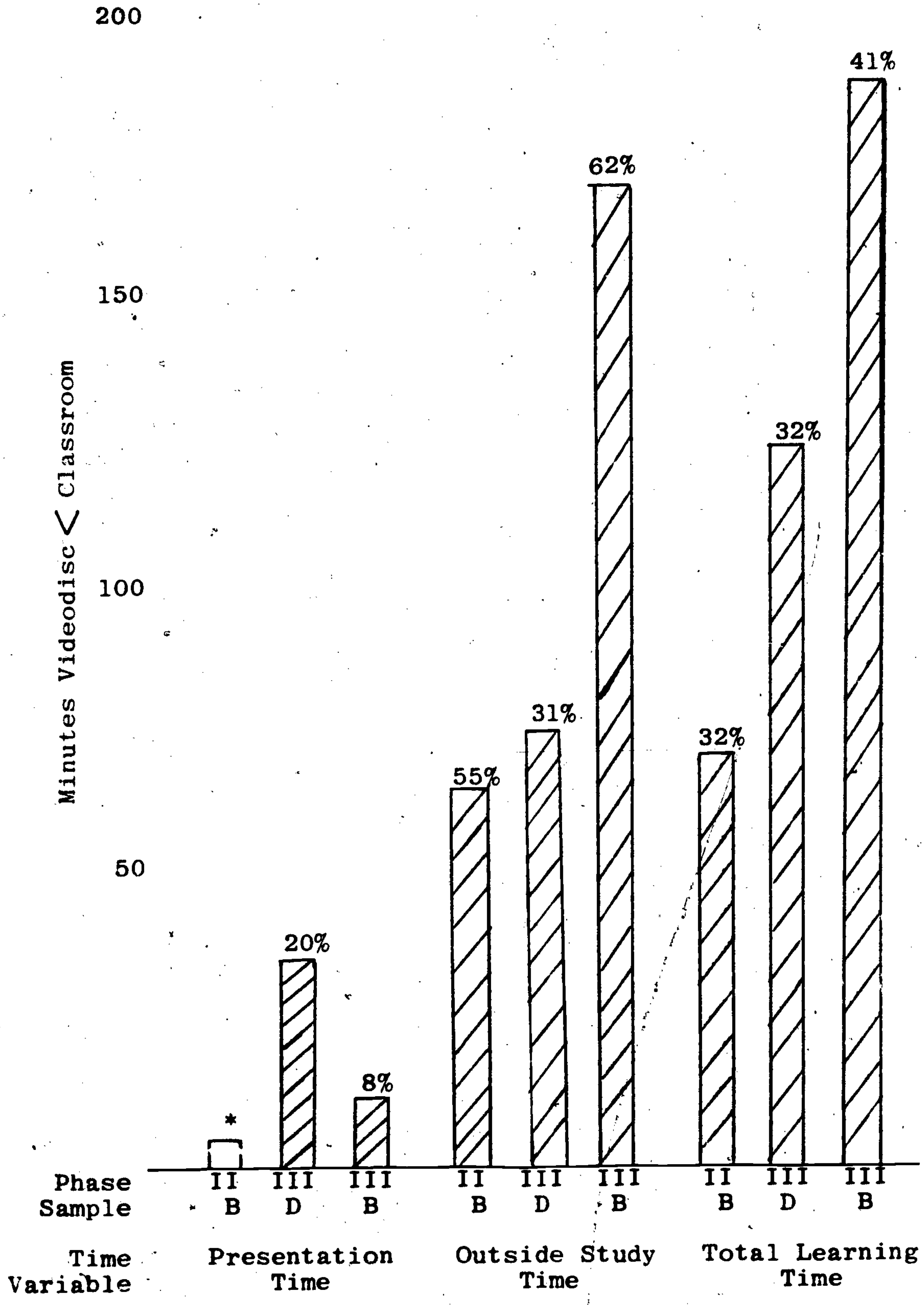
Instructional Time Comparisons
Videodisc vs. Classroom Groups

		Phase II			Phase III-BCC			Phase III-BYU		
		C	V	t	C	V	t	C	V	t
Presentation Time	$\overline{X}$	68.5	73.5	1.65	150.0	120.4	2.28*	150.0	137.6	1.84
	SD	0.0	12.1		0.0	30.3		0.0	29.2	
Outside Study Time	$\overline{X}$	113.9	51.0	2.09*	232.5	159.8	2.24*	265.3	101.0	6.27*
	SD	7.1	52.7		107.6	94.4		85.6	80.1	
Total Learning Time	$\overline{X}$	182.4	124.2	1.53	382.0	261.0	3.57*	415.0	234.0	6.26*
	SD	97.1	51.1		108.0	113.0		86.0	98.0	

*α < .05; t (.05) = 2.0

Figure 4

Instructional Time Savings Comparison
Videodisc vs. Classroom



42

*classroom<videodisc

2. Results of the Student Achievement Analysis

Table VIII presents summary statistics for the pretest, and post-test and retention test for each of the videodisc and classroom groups. The objective test includes multiple choice, true-false and matching items. The short answer test includes short answer items, fill in the blank and structured essay items. There are 58 points possible on the objective test and 42 points possible on the short answer test for a total possible score of 100 points. The results show no statistical differences between groups on any of the pretest scores. Significant differences are found between groups on all parts of the post test. The videodisc groups consistently outperformed the associated classroom lecture groups. These differences are greatly pronounced on the short answer portion of the test. The experimental design called for a retention test to be administered one week after the post test. However, due to a variety of factors which were not under the control of the researchers (school semester endings, student absences, student follow through in taking and returning the retention tests, etc.) sufficient data were not obtained on the retention tests to provide a valid comparison among groups on the retention scores. Half of the Phase III Dallas classroom and videodisc groups did not complete a retention test and two thirds of the Phase III BYU classroom group did not complete the retention test. A preliminary analysis of the retention tests which were returned showed that students from both groups were retaining their post test scores fairly well one week after instruction. Student scores were slightly lower on the retention test than on the post test. The videodisc student retention scores were consistently higher on each of the retention test short answer items than the comparison classroom students.

The videodisc student retention scores were consistently greater than the classroom retention scores particularly on the short answer items. This result should be viewed as a tentative finding which deserves further research, because of the small sample return problems noted above.

Figure 5 presents a graph of the pretest comparisons between videodisc and classroom groups. The results show no meaningful or significant differences on pre-achievement measures among groups. Figure 6 presents a graph of the post test achievement comparisons between groups. Figure 7 summarizes the post test improvement comparisons between videodisc and classroom groups. Comparisons are made relative to the classroom scores. The results show 8-16% increases on objective item scores, 24 to 73% increases in short answer items and 15 to 27% for total post test achievement scores. The short answer and total test score increases are statistically significant for each of the three videodisc vs. classroom comparison groups.

Table VIII

Achievement Comparisons Between
Classroom and Videodisc Groups

		Phase I	Phase II			Phase III Dallas			Phase III BYU		
		V	C	V	t	C	V	t	C	V	t
Pretest	N	26	24	25		25	28		73	24	
Objective	$\bar{x}$	21.5	21.0	20.0	.37	22.1	20.9	.70	20.0	20.4	.27
	SD	9.8	7.5	6.7		5.9	6.9		5.6	8.3	
Short answer	$\bar{x}$	4.0	2.4	1.5	.66	1.6	1.6	.00	2.0	2.5	.67
	SD	2.8	5.8	2.8		2.6	2.9		2.5	4.8	
Total	$\bar{x}$	23.2	23.1	21.4	.53	23.7	22.5	.56	22.0	22.9	.46
	SD	10.8	12.6	9.5		7.0	8.7		6.4	12.8	
Post-test	N	26	24	25		25	28		73	24	
Objective	$\bar{x}$	40.4	36.6	40.3	1.37	36.5	43.0	2.94*	47.1	50.0	2.00*
	SD	7.2	10.7	8.3		7.4	8.5		6.5	4.9	
Short answer	$\bar{x}$	24.8	15.0	25.6	3.04*	15.6	21.4	2.10*	30.5	35.6	2.72*
	SD	10.7	11.7	12.7		10.0	9.9		8.7	5.1	
Total	$\bar{x}$	65.2	51.6	66.6	2.55*	52.1	64.0	2.54*	77.4	85.7	2.65*
	SD	15.4	21.4	17.9		16.6	17.2		14.[illegible]	9.3	

* $\alpha = .05$

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Figure 5

Pre-Test Achievement Comparisons

Videodisc Groups vs Classroom Groups

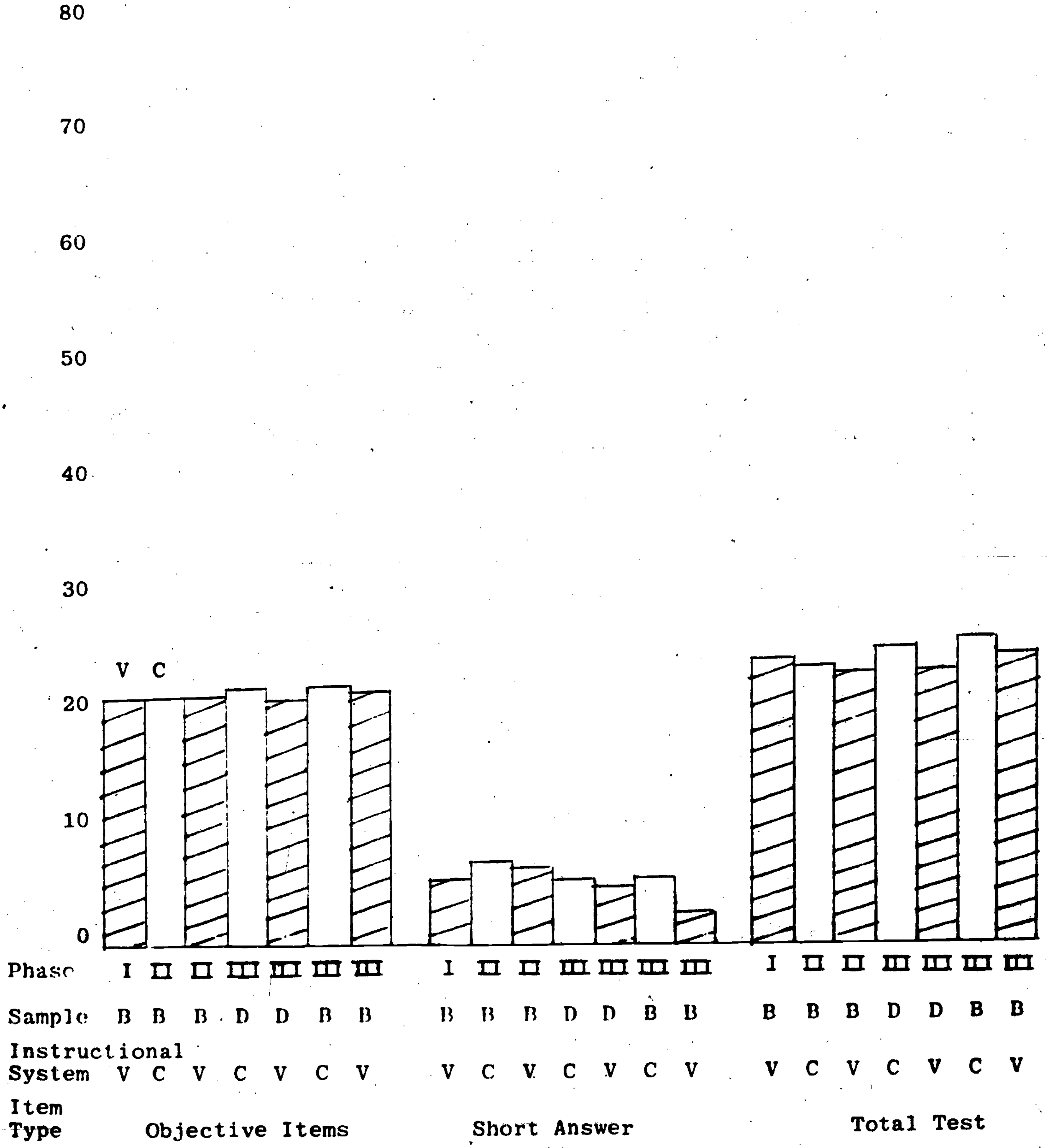


FIGURE 6

NSF PROJECT

Achievement Comparisons Between Classroom & Videodisc Groups

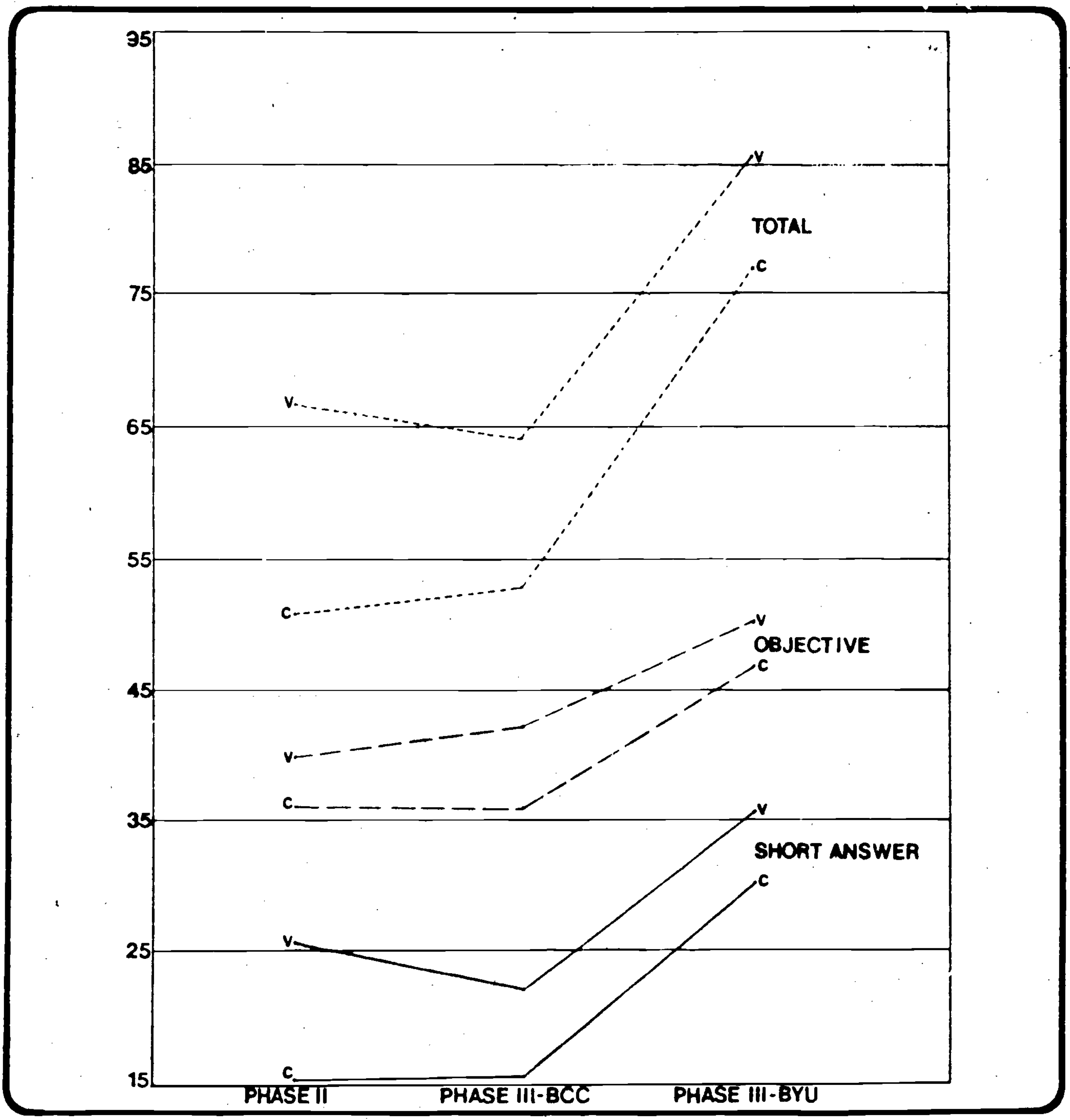
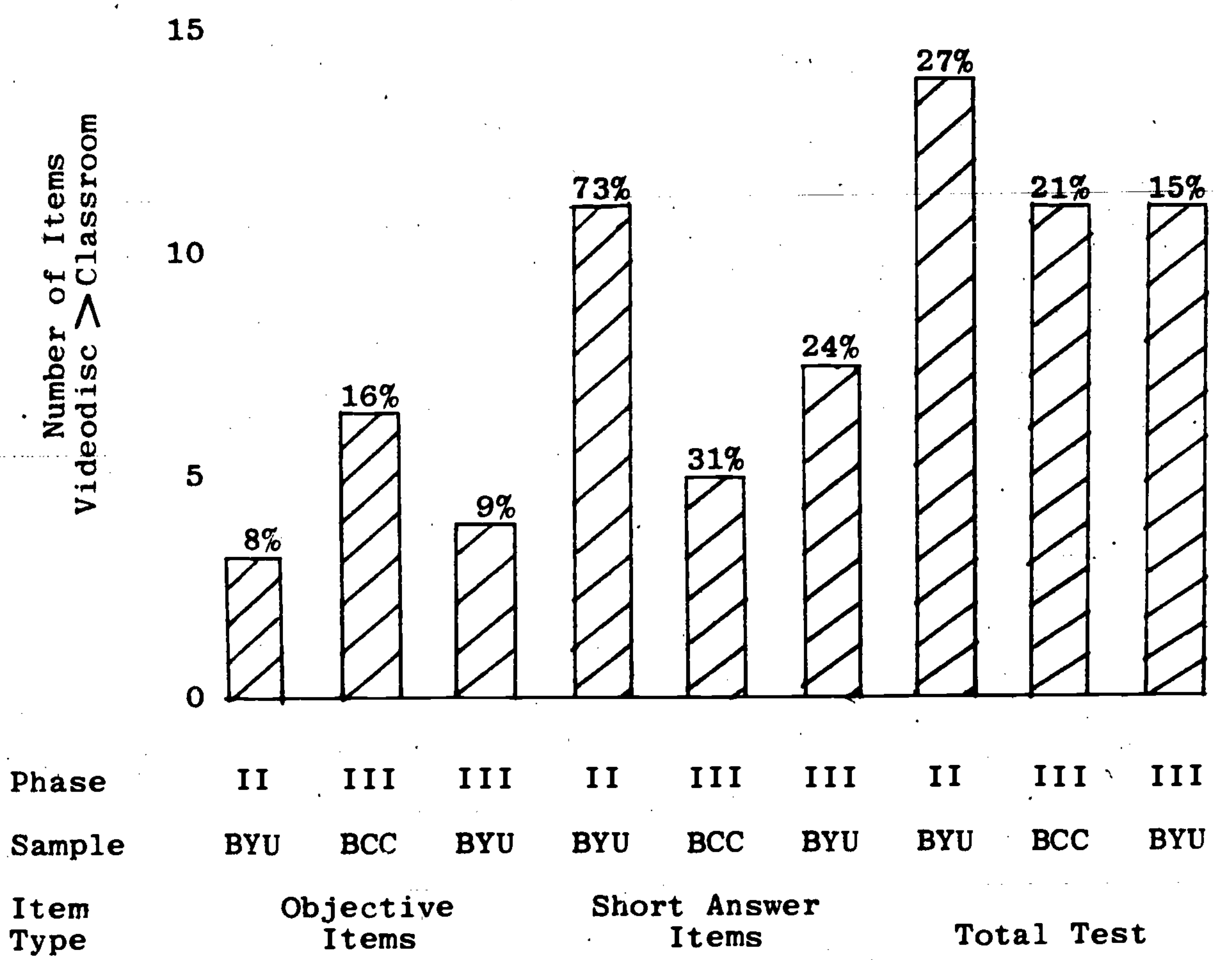


Figure 7

Post Test Achievement Improvement Comparisons

Videodisc Greater than Classroom



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3. Student and Teacher Reactions to Videodisc Learning

The following comments were most frequently made.

Things Liked About Videodisc Learning--

a) The ability to learn at my own pace
b) Ability to review materials easily
c) The interactive practice, answer and feedback frames
d) Motion sequences and visual illustrations
e) Lesson is well organized and thorough
f) The clarity and ease of understanding the content
g) Videodisc is interesting and attention holding
h) The rule frames
i) Videodisc saves time in learning
j) Could study materials a paragraph at a time

Things Disliked About Videodisc Learning--

a) Menus were displayed too often and too long to draw
b) There were hardware problems with the computer and videodisc
c) The computer was rather noisy and slow
d) Some concepts needed additional clarification
e) The videodisc screen was jittery
f) More instruction is needed on the use of the keyboard
g) Wanted audio for some of the still frames
h) Use earphones to reduce distractions

Needed Improvements--

a) Clarify definitions and explanations of a few concepts
b) Provide more motion sequences
c) Reduce screen jitter
d) Improve the speed and reduce the noise of the computer
e) Debug the computer and videodisc programs
f) Increase availability of videodiscs
g) Provide shorter videodisc study sessions
h) Provide more indepth study of topics with additional references and resources
i) Be able to move quickly and easily from section to section
j) Have the menu frame available when requested
k) Have a teaching assistant available for answering more indepth questions

The students felt the videodisc was significantly different from other learning experiences in the following ways: I could learn at my own pace; more interesting and better designed, the integration of text, motion and practice; I could test myself on the materials I could control what I wanted to learn; ability to review easily and the learning by computer.

The above results point out that students responded favorably to their videodisc learning experience because of its visual interactive and individualized nature. The students could go at their own pace, they found the instructional design to be more interesting, and they liked the visual variety of motion, text and graphics.

Table IX presents a list of sample student personal quotations concerning their videodisc learning experience. This table reflects significant positive reactions from videodisc learning. A full list of student comments and personal essays regarding videodisc learning is available from the authors. A particularly thorough letter from one student, relevant to the national needs discussed in this paper, is included in its entirety here:

> "I really enjoyed using the videodisc to learn this particular biology lesson. My level of attention and interest in the lesson was <u>much</u>, much greater than it would have been had I received the same information in class or from the textbook. Although there was lots of reading incorporated into the lesson, it didn't seem like such a chore since it was broken up into small, easy to handle units. Also, I think there was much less eye-strain from looking at the videodisc rather than reading from a typical textbook. The colors helped avoid the eye-strain and monotony, while keeping my attention and helping me to realize which concepts were the most important to remember. The short film-strips were helpful in showing the entire cycle of the processes and how it relates to life. The rules showed me which concepts were most vital, and in simplified terms, so that I could remember them. The short quizzes helped me a great deal in reviewing. But, despite how much I appreciated all of these facets of the lesson, I felt that the very <u>best</u> part of the videodisc program was the fact that <u>I</u> could control the speed of my own learning, and even control which things I studied, or participated in at all. That alone would have made this a far superior method of learning in my mind. Overall, I would definitely participate in any classes offered by videodisc."

Table IX

STUDENT QUOTES ABOUT VIDEODISC LEARNING

"If more videodisc were available, I would probably take them. I would not take more classes though."

"I feel more positive that I understood the things I learned."

"It made me feel more confident about my ability to learn the subject. It made biology seem clearer and more exciting. It made me want to learn more."

"I have more confidence in my ability to understand cell development."

"Before I thought I was very dumb when it came to biology. When I scored 100% on the practice exercises, it gave me confidence."

"I want to learn more now because I realized it can be fascinating."

"After going through the videodisc, I feel like I want to have more knowledge about biology for my major."

"You had more control over the pace of your learning."

"I am not afraid of the complexity of biology."

"There was no limit to learning."

"I was part of the learning process; controlled how much I learned."

"The videodisc made me realize that I could learn biology fast and easy. And if I were to learn this way it would further interest me in taking more biology courses."

"I was severely challenged to keep up with class. I had failed both previous tests. Now my hopes and confidence are greatly increased. I'm excited!"

"Too numerous to conclude - but I was fascinated because I was getting the picture. Vocabulary did not stop me as it does in class. I always knew I was on track. No wasted words."

"It was fun!"

"During classroom lectures I am able to understand material, but with the videodisc I was not only able to understand, but I was able to retain the information received."

"Kind of because before I hated the science field, but that was because everything was so vague to me. But this videodisc system really changed my attitude--I feel like I'll never forget what I learned about DNA and RNA. But I know I will or already have forgotten what I have learned in the lectures."

Students were asked to indicate their experience and rank order their personal preferences for each of several types of instruction. Table X presents the summary rankings for the videodisc preference for various types of instruction. Lower ratings are more positive. The mean ratings were adjusted for the number of students responding to each item. The most preferred types of instruction were the intelligent videodisc, small group discussion, and individual study, in that order. The least preferred types of instruction were by T.V., classroom lecture, laboratories and films. The fact that the majority of students had not experienced computer based instruction or laboratory instruction would account for the low ratings for these two types of instruction. These data support the general conclusion from our previous research among college students that the videodisc, classroom discussion and individual study are consistently preferred over classroom lectures. (Baillio, Bunderson, Olsen and Thomson, 1980).

From Table XI the conclusion is that the preferred places to study the videodisc lessons were the learning center, home and library.

Table XII presents the rankings of helpfulness of the various instructional components. From Table XII the conclusion drawn is that the rules, practice, answers and feedback frames were the most helpful instructional components.

In questions 10-45 students were also asked to indicate their level of agreement on a five point scale for several questionnaire items assessing student affective reactions to the videodisc learning experience. Standard Likert scale analysis was used to calculate average ratings for each item. Lower ratings indicate stronger agreement with the statement (strongly agree = 1, agree = 2, neutral = 3, disagree = 4, strongly disagree = 5).

The student attitudes toward videodisc instruction were very positive.

ITEM	$\bar{X}$
I would recommend the videodisc to my friends.	1.4
I would take another course with a videodisc.	1.3
Time passed quickly while I was using the videodisc.	1.7
The videodisc allowed me to modify the rate and speed of my learning.	1.3
The lesson allowed me to meet my own learning needs and interests.	1.8

Table X

Ranking of Preferred Methods of Instruction

	Phase I	Phase II	Phase III Dallas	Phase III BYU	Overall Rank
Computers	4	8	7	2	4
Videodisc	1	1	1	1	1
Small Group Discussion	2	2	2	3	2
T.V.	8	7	8	8	8
Films	5	3	5	7	6
Individual Study	3	4	6	6	3
Laboratories	6	6	3	5	6
Classroom Lecture	7	5	4	4	6

- Videodisc is most preferred method of instruction small group discussion is ranked second.

- The least preferred methods of instruction are T.V., films, laboratories and classroom lecture.

Table XI

Ranking of Preferred Places to Study Videodisc

	Phase I	Phase II	Phase III Dallas	Phase III BYU	Overall
Home	2	3	2	2	2
Dorm	6	6	6	6	5
Classroom	4	4	5	5	6
Learning Center	1	1	1	1	1
Library	3	2	4	3	3
Science Lab	5	5	3	4	4

- The Learning center is the most preferred place to study videodisc, the home was second and the library was ranked third.

- The dorm, classroom and science lab were the least preferred places to study a videodisc.

Table XII

Rankings of Most Helpful Instructional Components

	Phase I	Phase II	Phase III Dallas	Phase III BYU	Overall
Rules	1	1	1	1	1
Examples	6	5	5	3	5
Practice	2	2	2	2	2
Answer Feedback	3	3	4	5	3
Motion Sequences	4	4	3	4	4
Discussion	5	6	6	6	6

- The most helpful instructional components in order were rules, practice, answers and feedback, motion sequences, examples and discussion frames.

In taking this lesson I was challenged to do my best work.	2.2
The videodisc allowed me to be very actively involved in my own learning.	1.7
The videodisc allowed me to learn at a pace that was right for my ability.	1.5
My interest in biology has increased because of the lesson.	2.3
The videodisc materials were clear and easy to read.	1.8
The reading level and vocabulary were appropriate.	1.7
The computer screen was easy to read.	1.3
The videodisc screen was easy to read.	1.8
The keyboard was easy to read and use.	1.1
The lesson was clear and easy to understand.	1.7
The content was at the right level of difficulty.	2.0

The various instructional components were well received.

The practice problems were very helpful.	1.4
The answers and feedback were helpful.	1.3
The examples were good.	1.8
The lesson menus were helpful.	1.8
The motion sequences were important.	1.9
The rule statements summarized the important ideas.	1.7

The somewhat lower rating for rule statements would indicate that some of the rule statements should be improved.

A very interesting result is found in the examination of the following five items.

At the beginning of the course I planned to take additional biology courses.	3.3
A job relating to biology is more appealing after taking these lessons.	3.0
My interest in biology has increased because of these lessons.	2.3
I would take another course with a videodisc.	1.3
I would recommend the videodisc lesson to my friends.	1.4

All students were non-biology majors who were taking the class for a general education credit. At the beginning of the course they did not plan to take additional biology courses.

4. Learning Strategies with Videodisc Instruction

In attempting to delineate the student's learning strategies, we looked at usage of videodisc control options as an indication of which strategies and tactics were popular.

Use of Options. Several people would stop the motion sequences (using the "Stop" key) to take notes or to go back to see it again (using the ← key). When viewing a practice question frame, students would push the "Help" key to receive additional review of a concept. A few times, students looked up words in the interactive glossary by pushing the "Vocab" key. However, because of the machine's slow speed and occasional tendency to seek the wrong frame this option was not used very often.

Keys which did accomplish their task were used repeatedly. Even keys which were first pushed accidentally (for example, the "Tactics" key which is situated on the key pad next to the oft-pushed "Next" key) tended afterwards to be used again.

We hypothesized that those who branch out more from the linear path benefit most from the interactive system. This is based on the idea that those who acquire or already have an appetite for learning will be more adventurous and try more of the options than other students. These students would presumably have higher gain scores. We did indeed find that the small number of students who used many options also did have higher gain scores. However, these students also had somewhat higher outside study time. Therefore, we cannot yet isolate a "high-option-use" learning strategy as the cause of the higher scores.

There are several constraints in this study that probably inhibited students in their use of various options.

Firstly, several students felt rushed, indicating that it would have been better to split the unit into two sessions rather than try to complete it all in one three-hour session.

Secondly, machine errors during use of an option seemed to inhibit later use of that option.

Thirdly, students usually received only a few moments or minutes of verbal instruction from the observer in the use of options at the beginning of the lesson instead of going through the introductory unit on the videodisc which details their use.

Fourth, and probably most importantly, the limited duration of the study probably was not adequate for substantially reshaping or diversifying the learning strategy or strategies which the student had built up over 16-plus years of formal education.

Keeping these points in mind, the relatively small use of options among these students is nevertheless of interest as a possible indicator of significant increase in flexibility and diversity of learning strategies that could result from longer term use of the interactive videodisc system.

Textbook Use. The clarity and thoroughness of the videodisc presentation were appreciated as factors in increasing the students' confidence to handle biological topics (e.g. "You know, for the first time, I think I'm going to learn this stuff. I'm beginning to see how it all fits together.") The students' increased confidence seemed to lower the amount of outside study time needed. Some students may have felt confident enough to take the test with little or no additional study of the text. However, several students expressed a renewed desire to study the text, having greater confidence in their ability to understand it (e.g., "Maybe now I'll read my textbook and understand it.") Thus, although time spent by these students with the text was less than for non-videodisc students, their understanding of the textbook material, as evidenced by their test scores, was significantly greater.

Relevance of Lectures. Some students felt that the videodisc would constitute a fine self-contained course (e.g., "I'd like to learn everything this way.") Others desiring additional information or clarification seemed to prefer it as an adjunct to regular classroom instruction. Students liked the way the videodisc lesson made the most important concepts stand out (e.g., special "Rule" frames, etc.) since rules are often much more difficult to pick out in lectures.

Notetaking Tactics. In looking at notetaking strategies, we cannot discriminate between the effect of the videodisc instruction and variables related to the professor-student relationships. At BYU students were generally told to take notes if they wanted but that they might not need them. These students' notetaking generally dropped off quickly when they saw that there was ample practice in each of the concepts. On the other hand in Dallas, unless specifically instructed otherwise, most students took copious notes from beginning to end. We attribute this largely to the Dallas students "hanging on every word" of their professor, feeling that they would be tested on the material. The Dallas professor apparently went into great detail, and tested on it. Interestingly, the Dallas students who took copious notes did no better on the post test than those who took no notes. Thus at this point we cannot draw any causal relationship between notetaking tactics and learning efficiency.

Conclusions. Based on a 2-3 hour session we could not adequately distinguish between behavior changes which may simply be short-term adaptions to the new media format and changes which might indicate a more long-term diversification of one's repertoire of learning strategies. Nevertheless the increased confidence felt by students would seem to be good "raw material" for whatever personal investment ("psychic" or otherwise) that might be involved in a broadening of one's useable learning strategies. Even if the results of this present study are highly tentative they still constitute useful baseline data for longitudinal studies which may follow.

What we would like to do is 1) identify the aptitudes that help the high-gain-score videodisc students learn more, 2) determine the extent to which exposure to interractive videodisc learning enhances these aptitudes in the great majority of students and 3) see how well these aptitudes can be transferred by students to application in new and different learning stituations. The pursuit of these student learning strategies and the instructional delivery systems that enhance them is a matter of great interest in light of the high levels of learning efficiency and effectiveness that videodisc instruction has demonstrated.

5. Pre-Post Changes in Knowledge, Interest, Confidence, and Attention

Table XIII presents the pre-post ratings for all videodisc groups on knowledge, interest, confidence and attention in Biology and attention in college major. Higher ratings are more positive.

The results show significant increases in student ratings of knowledge and confidence in biology. The ratings of attention with the videodisc were also significantly greater than student ratings of attention in biology and attention in their college major subjects. The videodisc is very effective in holding student attention. Students also feel more knowledgeable and confident about biology following a videodisc learning experience.

Role Commitment Changes. Table XIV presents the pre-post comparisons between role commitment classifications. The role classifications were practical learner, interested lay person, future specialist and research scientist. This table shows the following significant findings. First, the role classifications for the majority of students did not change as a result of a two-hour experience with videodisc learning. However, 7 out of 45 students (16%) changed their role classification from a practical learner to an interested lay person. Also 2 out of 20 students changed their role classification from a future specialist to research scientist. Three students (one from each of the three pre-role classifications) indicated a lower role classification on the post-role than on the pre-role. An overall summary would then indicate that ten of 97 (10%) of the students increased their role commitment while 3 of 97 (3%) decreased their role commitment. Since role commitments are generally

Table XIII

CHANGES IN KNOWLEDGE, INTEREST CONFIDENCE AND ATTENTION FROM VIDEODISC INSTRUCTION

	PHASE I	PHASE II	PHASE III Dallas	PHASE III BYU	PAIRED T-TEST
Knowledge					
Pre	2.7	3.5	3.6	3.4	4.95*
Post	3.1	3.8	4.5	4.0	
Interest					
Pre	3.9	4.0	5.3	4.6	1.25
Post	3.9	4.2	5.3	4.4	
Confidence					
Pre	2.6	3.2	3.5	3.7	4.88*
Post	3.0	3.7	4.4	4.1	
Attention Biology					
Pre	5.1	4.8	5.4	5.4	.35
Post	6.1	5.9	5.6	5.1	
Attention College Major					
Pre	6.1	5.8	5.5	6.0	1.30
Post	6.1	5.9	5.9	5.9	
Attention College Major	6.1	5.8	5.5	6.1	18.6*
vs.					
Attention Videodisc	6.3	6.0	6.0	6.4	
Attention Biology	5.1	4.8	5.4	5.4	17.0*
vs.					
Attention Videodisc	6.3	6.0	6.0	6.4	

* $\alpha < .05$; t(.05)=2.00

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based on a lengthy history of prior experiences and expectations with a particular subject matter area, one would not expect role commitments to be easily changed during a short term instructional experience. The fact that the videodisc learning did result in demonstrated role commitment enhancements is indeed an important variable which deserves much more investigation over a longer time frame.

VI. WHAT'S NEXT

In this concluding section, evaluation results will first be discussed and an attempt made to integrate them within a coherent framework. Then some recommendations will be made for three important future directions.

Discussion of the Results

Hardware and software are now viable, but will continue to evolve dramatically. The evolution of this project through three different microprocessors and two different videodisc players says clearly that the hardware and software are not mature. In addition, an effort to utilize two screens to get higher resolution and graphics on one screen proved not to be advantageous in this project. This is not clear that a one-screen approach is superior to a two-screen approach for every application. Indeed, it is not even proof that in this application, given a fast processor not burdened down by floppy disk accesses, a second screen for status information may have been useful. However, given the current state-of-the-art it seems that the greater simplicity of the one screen system would be desired. Ideally, a medium to high resolution color display that could also show an NTSC video display with good color would be desirable.

Miniaturization will be important in the future, both for the microprocessor and for the videodisc player. An interactive videodisc system as small as a regular-sized audio cassette player would have major advantages of portability and cost not found in present configurations. Projections in the electronics literature for integrated circuits certainly make the computer portions miniaturizable. A 32-bit central processor with one million bits of random access memory will be available on one chip in the 1985 time frame. In that same time frame, magnetic bubble memories in the megabyte range will be available. Computer programs could be downloaded from the videodisc into the bubble memory for very rapid execution thereafter. If desired, a small portable (possibly hand-held) terminal could attach either temporarily or through telecommunications to a main storage station, containing a data base on student progress from all of the students working in a given location.

Videodisc systems also promise to become miniaturized in the 1985 time frame. One example that will soon be on the market is the Philips compact disc system. This 4" optical disc has been designed for PCM audio, but it holds several billion bits of digitized audio and is as small as an audio cassette player. Another proposal which has received some publicity is that of the Digital Research Corporation for a small optical card that would fit in a shirt pocket. A 3x7" card would contain up to 30 minutes of compressed video, or any combination of video, audio, and computer programs that could fit into that capacity.

Thus, while intelligent videodisc systems over the next few years will be large and more costly, and less portable (as is the prototype in Figure 1), this can change radically over a period of four to six years. A first step might be to have a hand-held microcomputer that could control one of today's videodisc players remotely. At a later step, both the microprocessor and the videodisc system (possibly still packaged separately) would be much smaller and more portable. The videodisc player would tie into a higher resolution color monitor suitable both for computer graphics and for video displays.

Increased Sophistication of Programming Yields Diminising Returns for Fixed Objectives. The series of studies in this project provide many data points to evaluate videodisc instruction. The data points range from an effective instructional presentation implemented on a manual videodisc through modest computer enhancements to quite sophisticated computer enhancements. The question arises as to what the additional cost in programming time, hardware and software time yields, in terms of measured objectives. Since numerous objectives were measured in this project, some answers are beginning to emerge.

Figure 8 plots the post test scores on the reliable post test for unit 2 as the ordinate and a conceptual cost curve as the abscissa. No metric was established for the cost dimension, so the curve is conceptual. It is based on an ordering that assumes the Phase III intelligent videodisc as currently the most costly and the three-hour lecture as clearly more costly than the 1½ hour lecture. Figure 8 shows that there is a diminishing return curve starting with the point for zero cost effort (students score on the pre-test, based on prior knowledge and test-taking abilities). Another key point on the curve is instruction with excellent teachers who devote an hour and a half to the subjects measured. This represents the "current state-of-the-art" in classroom biology teaching of some difficult concepts. We see that the manual videodisc does a significantly better job than an outstanding classroom teacher who takes 1½ hours. We also see that the addition of the computer enhancements to this same manual disc do not give us any meaningful increases on the fixed objectives measured by the posttest. Going further out the curve, we see that by doubling the amount of time given in class and requiring additional outside study time of students, the conventional system can exceed the manual videodisc, but that when we pull out the stops and provide an intelligent videodisc system at some additional cost, we get about as far out on this particular curve as it would be cost-effective to go. To go further we would really want to extend the depth and coverage of the objectives as measured by the posttest and get the students involved in the procedural and causal knowledge much more deeply than was possible in this study. Also we would want to measure the affective objectives, the role commitment, etc. to evaluate the payoff of the extra cost for intelligent videodisc systems.

Figure 8 should help decision makers judge which mixtures of currently available systems they wish to use--classroom teachers, the manual videodisc system, or the intelligent videodisc system. Currently the answer to this question for any organization probably depends upon the quality and availability of the teaching staff and the extent to which education must be distributed to locations where qualified teachers are not available. Figure 8 is promising because it gives a number of new choices for educators in colleges, high schools, industry, and the military.

Videodisc Used in Lecture Yields Promising Gains. A question arises in looking at Figure 8: What would happen if an instructor were equipped with a manually controlled videodisc? This question, raised by the participating instructors, was so intriguing that a carefully-controlled study was conducted by WICAT in cooperation with Dr. Darrell Weber at Brigham Young University. Dr. Weber taught another section of the same Bio-Ag 100 class evaluated in the previous studies. Unlike the previous teachers however, he only gave one hour to DNA, RNA, and protein synthesis. His lecture was illustrated by an excellent movie and by transparencies so it represented a high quality contrast to the manually-controlled videodisc. One-half of Dr. Weber's students were

Figure 8

Diminishing Returns in Achieving Specific Educational Objectives

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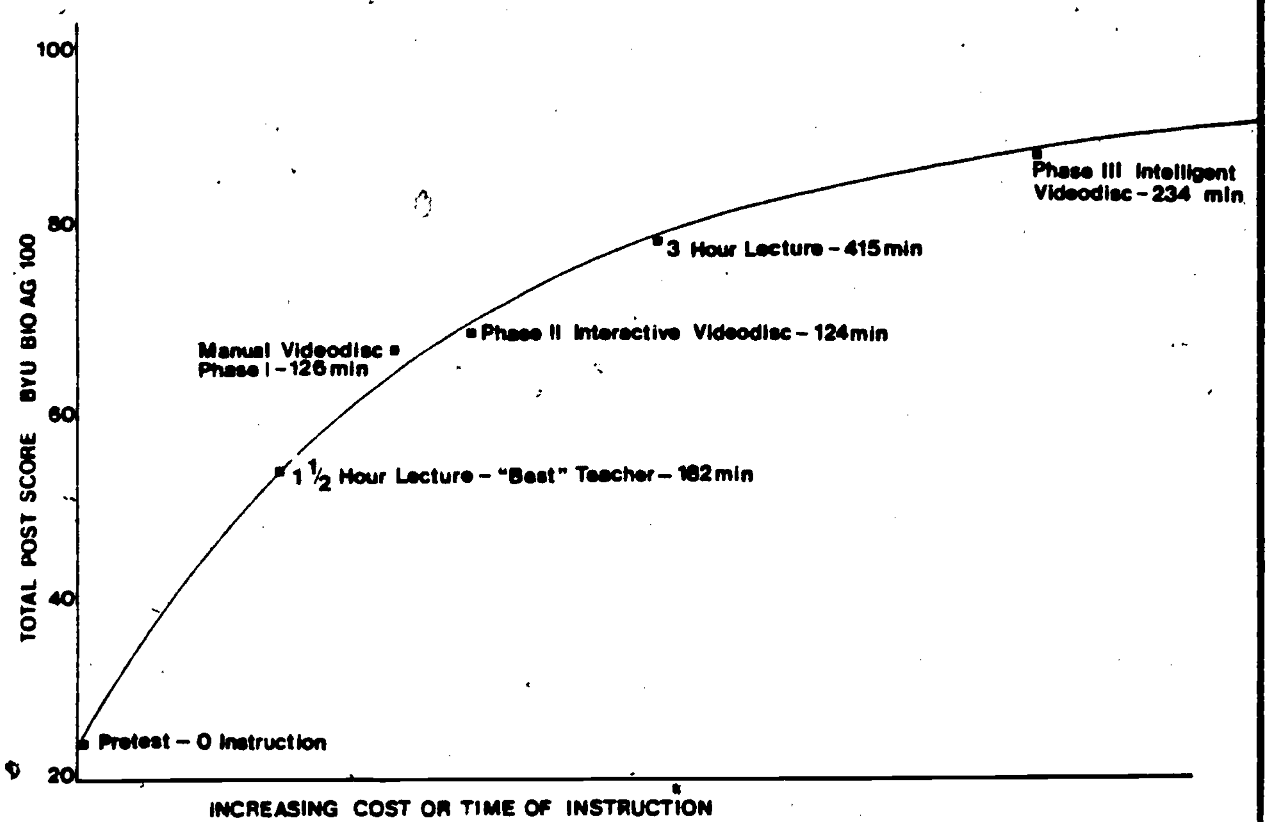

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dismissed one day and the other half received the regular lecture with audio-visual adjuncts. Next session, the first half received a lecture utilizing unit 2 of the intelligent videodisc system. Dr. Weber presented the rules and examples, the motion visuals, and fifteen practice problems. He used the random-access and freeze frame features under his pacing and control. The students were so involved in the situation and confident after having seen the rules that they called out the answers and were given immediate feedback (shown to them on subsequent answer frames). There was a tremendous electricity and excitement in the room. The students were extremely involved and afterward commented positively on the experience. More importantly, the scores on the posttest given to the videodisc group were over one grade higher--10 points on the carefully constructed and reliable posttests used in all these studies. Figure 9 plots the one-hour audio-visual lecture and the one-hour videodisc lecture on the same diminishing reference curve, in context with the other activities. It is remarkable to note that the videodisc pushed the one-hour lecture past the department's best teacher with the 1½ hour lecture. This finding yields yet another important alternative for science educators. It points the way to some immediate gains that can be obtained in a much larger number of classrooms in a shorter time frame.

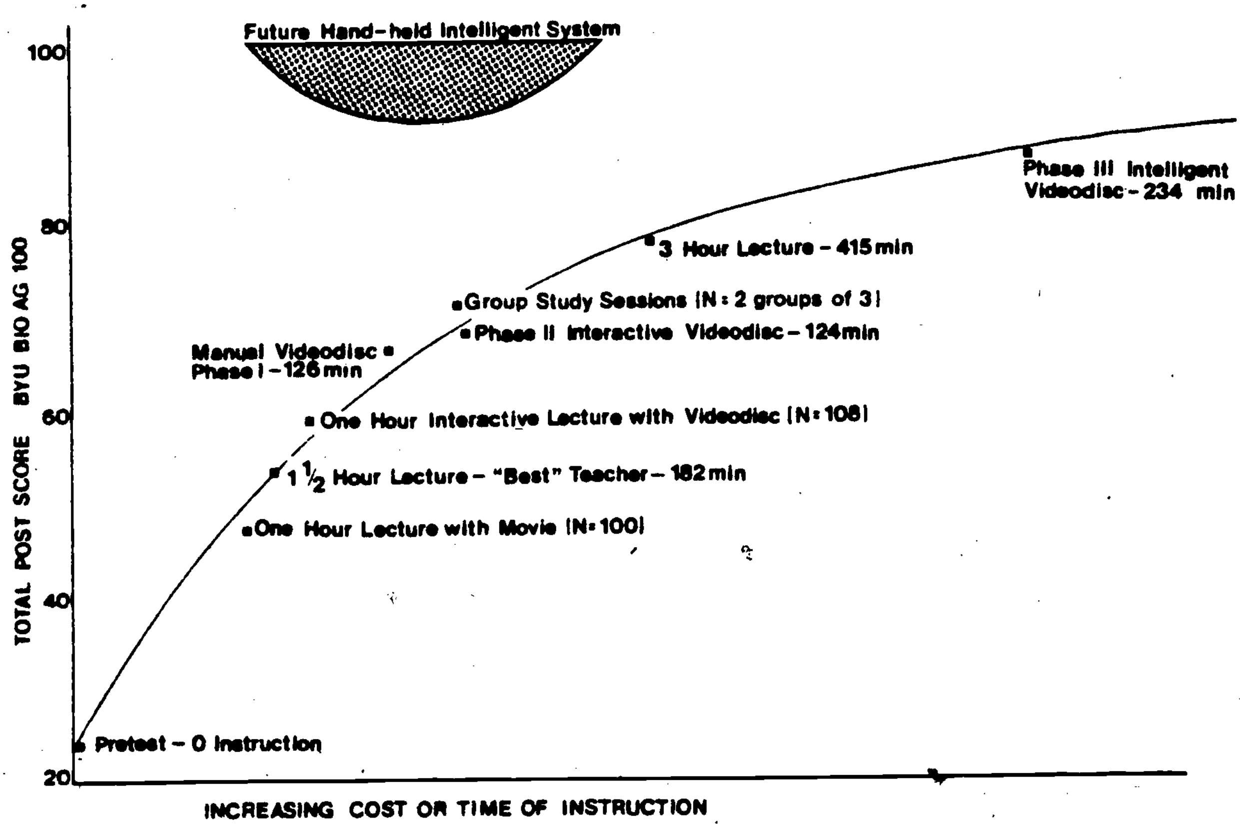
The classroom videodisc study was one dealing with the effectiveness of the system in different learning settings. Another setting for implementing videodisc learning is the small group, meeting around the videodisc system for an after class "help" session. This was investigated as an adjunct to Dr. Weber's class.

In the class of 100 students above, 6 students missed both of Dr. Weber's lectures on DNA, RNA, and protein synthesis. These six students, along with two others who merely wanted to reinforce what they had learned in lecture, attended a help session taught with the videodisc. The eight students attended in two groups of four.

The achievement test scores of this help section were nearly as high as some averages from the Phase III videodisc group. The help session average score was 21 points higher than Dr. Weber's control group average. (A more detailed description of this study is available upon request from the authors.) These results point to another important application of videodisc technology in the teaching process.

Figure 9

The Impact of an Interactive Videodisc on a One-Hour Lecture.
Future Intelligent Videodiscs



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Concluding Comments on Cost/Effectiveness. Costs will continue to be a major driving factor in the introduction of videodisc systems. This section summarizes some ways to think about costs to achieve different levels of effectiveness.

Figure 9 has a shaded area near the top which represents a future hardware and software configuration for videodiscs, This area is presented to remind the reader not to quote this paper to prove that manual videodiscs are the most cost-effective solution to science education problems like the one studied here. It is clear that videodisc and microcomputer technology are not yet mature and that smaller, more inexpensive models will in all probability emerge. The cost and time savings potential from future intelligent videodisc systems are likely to compete favorably with any other alternative, and be usable both by experienced teachers and by students. In addition, where quality teachers are not available, the intelligent videodisc system today and increasingly in the future will provide a cost-effective alternative.

The two intelligent videodisc projects (WICAT and the University of Utah) were reviewed by a team of advisors, Dr. Roger Heyns, president of the William and Flora Hewlett Foundation, Dr. Wilbert McKeachie, Professor of Psychology and Director of the Center for Research on Learning and Teaching at the University of Michigan, and Dr. Lindon E. Saline, head of Corporate Employee Relations at the General Electric Corporation. These advisors will each prepare a report on the broader implications of intelligent videodisc technology.

At the final panel briefing, when Figure 9 was discussed, the panelists pointed out that the shape of the curve was, even now, deformed from what is shown in Figure 9. Not only will the phase III videodisc evolve toward the dotted circle segment depicted in the figure, but the c st of human instructors for 1, 1½, 3 hours, etc. will increasingly exceed the cost of intelligent videodisc systems. In computer science and some branches of engineering, for example, the national shortages for scientists and engineers have bid up the salaries of these professionals so high that they cannot afford to teach. Increasingly, society is going to have to face the true costs of unproductive educational delivery, and consider the various alternatives, several of which are depicted in Figure 9. This point is summarized in Figure 10.

Figure 10

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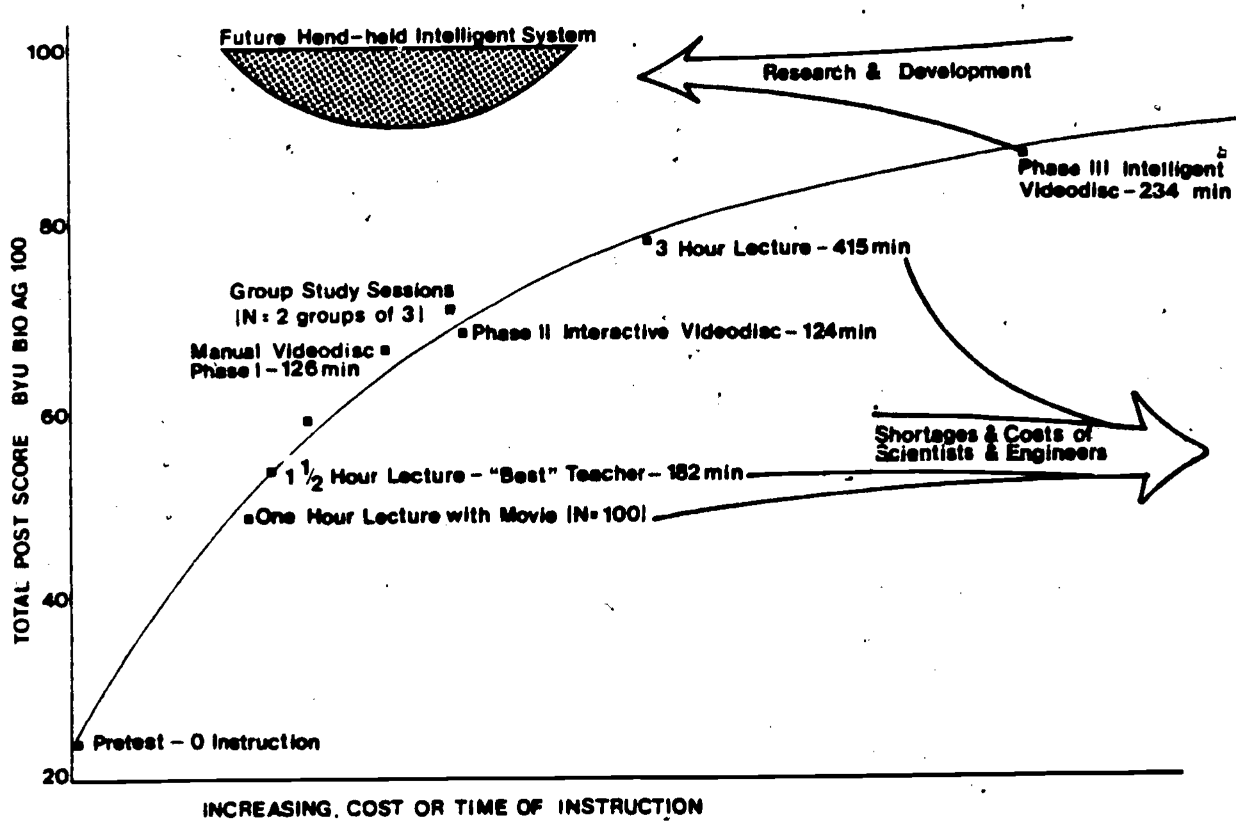
The Impact of R&D on Videodisc Costs, & the Impact of Labor Shortages on Lecture Costs



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Future Directions

Three categories will be discussed, dealing with the research issues that need to be resolved, with some short-range recommendations, and with some longer range recommendations.

Many Research Issues are not Resolved. Because of the complexity of the hardware, software, and courseware development in this project and the short amount of time left for evaluation, many research questions that could be answered using the current hardware, software, courseware configuration were not answered. For example, we were not able to evaluate the efficacy of the conversational games, the interactive glossary, and other features in promoting the acquisition of conversational knowledge. We were not able to evaluate the lab guides and simulations on the extent to which they teach procedural knowledge. We were not able to evaluate the extent to which the simulations and other features promote causal knowledge, although some pilot work in a special laboratory class was most promising. Students using the electrophoresis laboratory were observed going through thought processes with one another and with paper and pencil that represented high levels of performance in predicting experimental outcomes based on causal principles.

The equipment labs were seen by the BYU teachers responsible for biological laboratory equipment operation to be a promising solution to some serious dilemmas. When universities and colleges can afford expensive equipment, they often cannot afford the spare parts and specialized personnel to keep the equipment operating and to teach students to use them. The more expensive equipment is not available to the students or is available only under very restrictive circumstances. Two-dimensional simulations on intelligent videodisc systems offer a way to surmount these problems and provide effective conceptual experience in using any of a wide variety of expensive lab equipment. More practice trials, more situations, more simulated experiments with immediate feedback can be run with the videodisc than with the real equipment itself, even if it is working and the graduate assistants are knowledgeable, and even when the students can get access to it. More importantly, many colleges, high schools, and even universities do not have access to the equipment at all so their students are not given any opportunity to learn its use. By disseminating intelligent videodisc systems this problem could be overcome. As mentioned in the section on national needs, the rapid increase in technology in all sectors of our society is a major driving force behind the difficulties being encountered in military, industry, and education in operating and maintaining new technological systems. Intelligent videodiscs should be further developed because they offer promise for overcoming this problem. WICAT has had excellent results in teaching maintenance procedures on complex radar and missile systems for the Army, and in vehicle repair for an automotive company.

Whole classes of laboratory simulations should be explored in greater detail. The experimental laboratory paradigm illustrated by the electrophoresis experiment on this disc needs further exploration, but in biology there are a couple of other laboratory paradigms that deserve serious exploration. One of these is the classification laboratory. Biology in its various branches predominantly deals with conversational and classification knowledge at the present time. Some classification procedures require procedural knowledge, as in keying out an organism by checking it through a binary decision tree. However, students are not able to have access to many organisms to learn classification and identification. The organisms mature at different times of the year and in different parts of the world. They are difficult, expensive, or dangerous to obtain. The videodisc can provide such a wide variety of close-ups, micrographs, shots of different aspects and features of the organisms that classification and identification are possible. Thus, experience with a much wider variety of organisms could be provided. The current method of teaching verbalizations and giving practice in a group with a few dried up specimens could be replaced with a much richer experience.

Another biological laboratory paradigm is the field trip. These are going out of style because of fuel costs and other costs. A videodisc field trip could lead the learner through a variety of interesting environments. The learner could see ecological relationships on his video field trip as well as identifying organisms in their natural habitat.

Some of the most pressing national needs deal with the lack of motivation and interest in scientific subjects. The promising preliminary results related to role commitment, and the fairly solid and substantial results in terms of interest and motivation in favor of the videodisc may need to be explored in other contexts with other student populations and other subject matter areas. The roots of this increased motivation need to be explored. Video is a warm medium and truly video has a tendency to draw people in. Interactivity and control, however, are other dimensions involved in motivation and interest, as are the powerful learning effects apparently due to the rules, practice pages and answer pages. It is not clear which of these or what combination is most important.

Short Range Recommendations: Both Intelligent and Manually-Controlled Discs Have Considerable Promise. For science education in high schools, colleges, and universities manually controlled discs have great immediate promise. They are also promising in industrial and military classroom settings where good teachers are available. This is because the hardware costs for the manual players are much lower than for computer-controlled systems, yet the results are very good. Manually-controlled branching players, like the Pioneer, Magnavox Mark II, or either of the industrial education players (DiscoVision Associates or Sony) can become much more widely disseminated throughout classrooms in a shorter period of time than the more complex computer-controlled systems. Computer systems and interfaces are also far from standardization, while the optical videodisc standard is with us and available from several compatible sources. Despite the threat posed by capacitance pick-up videodisc systems being marketed by RCA and JVC, the optical standard seems to be firmly entrenched, at least for education and training. Thus, publishers of discs can see the promise of a meaningful-sized market for the distribution of manual discs. The data in this study show how much well-designed manually-controlled discs can enhance both classroom learning and individual self-study.

Intelligent videodisc systems are now available from several sources and are cost effective in many applications, especially in military and industrial training and job-aiding. Stand-alone intelligent videodisc systems now available commercially range in price from a low of about $6,000 to upwards of $15,000. When four or more work stations share a processor and fast magnetic disk drive, the price per station can be as low as $4,000. Industrial or governmental organizations are not advised to wait for the eventual low-cost portable systems that will probably emerge in a number of years, but to begin the investment in disc and program development, and in learning how to implement the systems. This investment can have short-term pay off in numerous distributed and local education/training situations. Equipment simulations for operations and maintenance have been mentioned. Highly effective education where good teachers are not available is another area of immediate payoff. The investment in videodiscs is not lost, because the cost of transfer to a new generation of videodisc system will be a small fraction of the original development cost. The computer software investment should be based on a processor and a language with a longer future It would be unwise to develop large amounts of interactive computer courseware in the inconvenient languages and small memories of current 8-bit personal computers.

Intelligent videodisc systems can also be used in education. One or two systems could teach a group of rare, low-enrollment courses for which faculty were not available or interested. Teaching the use and maintenance of laboratory equipment is one example. Teaching Old Church Slavonic is another. One or two systems could be used for research and development. Publishing a videodisc may soon have as much professional and economic payoff as publishing a textbook.

Long-range the greatest promise is for small, simple intelligent videodisc systems. As mentioned above, the hardware and software are far from mature for intelligent videodisc systems. The future will show increased miniaturization and increased power. The future miniaturized systems have considerably greater promise than the manually-controlled discs, despite the great short-range promise of the latter. The future hand-held microproce sors can be used by teachers for manually-controlled presentation of the discs, but can also provide all of the advantages demonstrated and suggested for the intelligent videodisc systems. Figures 9 and 10 include our prophecy of the cost-effectiveness of the small, inexpensive, and simple intelligent videodisc systems of the future. Certainly, these products are worthy of substantial investment in their development. Certainly, these new technologies (optical memories and large-scale integration of computer circuits) combined with network communications have the promise of influencing education and training in public education, industry, and the military as profoundly as did the printing press in its day.

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REFERENCES

Baillio, B., Olsen, J.B. Bunderson, C.V. and Thomson, W. "An Intelligent Videodisc System: An Evaluation in Developmental Biology". First Annual Report. Learning Design Laboratories, WICAT Inc., 1160 S. State #10, Orem, UT July, 1980.

Bunderson, C.V. "A Causal Framework to Describe Training Needs and Requirements in the Department of Defense". Technical Report No. DIS-1, Learning Design Laboratories, WICAT Inc., November 1, 1979.

Bunderson, C.V., Olsen, J.B. "A Comprehensive Model of Learning and of the Supporting Teaching System". Technical Report #1 for the General Electric Company, Learning Design Laboratories, WICAT Inc., January 1980.

Bunderson, C.V. and Campbell, J.O. "Videodisc Training Delivery Systems and Videodisc Authoring/Production Systems: Hardware, Software, and Procedures". Final Report, Volume I, Learning Design Laboratories, WICAT Inc., June, 1979.

Campbell, D.T. and Stanley, J.C. Experimental and quasiexperimental designs for research. Chicago: Rand McNally, College Publishing Company, 1963.

Helgeson, S.L., Blosser, P.E. and Howe, R.W. The status of pre-college science, mathematics, and social science education: 1955-1975. Volume 1. Science education. Report to the National Science Foundation, Contract No. C762067. Center for Science and Mathematics Education. The Ohio State University, 1977.

Science and Engineering Education for the 1980's and Beyond. National Science Foundation and Department of Education, October 1980.

Science Education Databooks, National Science Foundation, Office of Program Integration, Directorate for Science Education, Report SE80-3, 1980.

Stake, R.E. and Easley Jr., J.A. Case studies in science eudcation. Report to the National Science Foundation, Contract No. C7621134. Center for Instructional Research and Curriculum Evaluation and Committee on Culture and Cognition, University of Illinois at Urbana-Champaign, January 1978.

Weiss, I.R. Report of the 1977 national survey of science, mathematics, and social studies education. Report to the National Science Foundation, Contract No. C7619848. Center for Educational Research and Evaluation, Research Triangle Institute, March 1978.

Wirszup, I. Letter of correspondence concerning a series of six reports prepared by Wirszup on the Soviet Educational System. University of Chicago, Department of Mathematics, 1979.

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