ABSTRACT
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interactivity offered by microcomputers have not been fully
investigated by videodisc designers or science educators. The
Videodisc Project Group, a subsection of Educational Technology
Center's New Technologies Group, is: (1) conducting research on the
educational effectiveness of videodiscs for teaching science; and (2)
studying the process of videodisc creation by designing, producing,
and evaluating an interactive videodisc. This document is designed to
provide a status report on the research. The research videodisc,
designed for use with middle school students, presents science
subject matter in a manner that both illustrates and elicits the
application of scientific modes of inquiry. It utilizes existing
science television programs from the WGBH Educational Foundation and
the Children's Television Workshop and will be produced using the
authoring system Authority (TM), developed by Interactive Training
Systems, Inc. The process of creating the research videodisc revealed
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Because of the unchangeable nature of existing visuals, retrofitting
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content and instructional variety are important. (Author/CW)

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THE ETC SCIENCE VIDEODISC PROJECT: A REPORT OF RESEARCH IN PROGRESS

Technical Report

July 1985

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THE ETC SCIENCE VIDEODISC PROJECT:

A REPORT OF RESEARCH IN PROGRESS

<u>TECHNICAL REPORT</u>

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SCIENCE VIDEODISC PROJECT   :
NEW TECHNOLOGIES GROUP
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HARVARD GRADUATE SCHOOL OF EDUCATION
CAMBRIDGE, MASSACHUSETTS

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EDUCATIONAL TECHNOLOGY CENTER

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Acknowledgements

Contents

REPORT ABSTRACT

The teaching and learning opportunities created by combining existing television programming with the kinds of interactivity offered by microcomputers have not been fully investigated by videodisc designers or science educators. The Videodisc Project Group, a subsection of ETC New Technologies Group, is: (1) conducting research on the educational effectiveness of videodiscs for teaching science; and (2) studying the process of videodisc creation by designing, producing, and evaluating an interactive videodisc.

The research videodisc, designed for use with middle school students, presents science subject matter in a manner that both illustrates and elicits the application of scientific modes of inquiry. It utilizes existing science television programs from the WGBH Educational Foundation and the Children's Television Workshop and will be produced using the authoring system Authority (TM), developed by Interactive Training Systems, Inc.

The process of creating the research videodisc revealed design opportunities and constraints for retrofitting videodiscs. Because of the unchangeable nature of existing visuals, retrofitting is a difficult method for creating educational videodiscs in which content and instructional variety are important.

The future evaluation of the videodisc will test a variety of interactive formats and use patterns for teaching science-process skills.

INTRODUCTION

The ETC New Technologies Group is charged with examining the educational implications of emerging technologies. Emerging technologies are devices not yet in wide use in the nation's schools but which show considerable future promise. Prominent among these new technologies is the interactive videodisc. The Videodisc Research Group, a subsection of the New Technologies Group, was formed to research issues related to the design, application, and evaluation of videodisc technology.

The present report states our research questions and explains how and why we chose them. It summarizes our research progress to date and outlines a plan for future studies.

Our research questions derive in part from our reading of research on educational applications of videodiscs. Thus we begin with a brief literature review, focusing chiefly on the areas where promising lines of inquiry seem to call out for additional research.

RESEARCH RATIONALE

The unique technical capabilities of the interactive
(optical, laser-based) videodisc include the capacity for
presenting moving video, video stills, audio, text, and graphic
information in a nonlinear format under user control. The
computer can intersperse the video with text and/or graphics or
can overlay this information over moving or still video in any
combination that suits the design objective. Interactive
videodiscs also have the technical capability to store a great
amount of video and audio information--up to 30 minutes of linear
motion video, 54,000 still frames, 20 hours of still frame audio
with two sound channels--and provide rapid and precise access to
any single image. (See Appendix A for a more detailed explanation
of videodisc technology.)

Videodisc technology is now used for entertainment, surrogate
travel, medical education, military, industrial, and corporate
training, and for the storage of visual databases (Kearsley,
1981; Gupta, 1982; Hon, 1982; Reeves et al., 1982; Butler, 1983;
Butterfield, 1983; Graham, 1984). However, few comprehensive
studies have been conducted to indicate the possibili'ies and
limitations for school application raised by this technology.
The high cost of purchasing videodisc hardware and of creating
videodiscs, the limited number of quality videodiscs designed for
classroom use, the limited availability of videodisc players in

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the schools, and the related reluctance of videodisc developers
to invest in the field of education has meant that educators
have had little opportunity to study the pedagogical questions
posed by the new technology.

A. The Potential of Interactive Videodiscs for Education

Knowledge of how to make the technical capabilities of
videodisc work to enhance current methods of teaching and
learning is critical to successful application of videodisc
technology in schools. We reviewed the videodisc literature to
identify promising videodisc instructional models and strategies,
particularly for teaching science.

Interactive videodiscs developed for business and industry as
well as for educational and school use generally fall into three
instructional models: tutorials, visual databases, and
simulations (Kearsley, 1981; St. Lawrence, 1984). Tutorials
consist of how-to courses that help a user master a new subject
or skill, such as tumbling or a foreign language. Sometimes
referred to as "electronic tutors," videodiscs designed according
to this model interact with students like a teacher. They
provide explanations, examples, corrective feedback, and guidance
(Currier, 1983). Visual databases contain collections of images
in specific subject areas such as art or biology and often serve
as archives of visual information (Levin, 1983). Simulations
provide learners with an opportunity to explore facsimiles of

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real-world situations and complex systems. Presented with a
hypothetical situation that is under their control, students must
alter variables and make other decisions that will directly
influence future events. By collapsing time, simulations
illustrate the outcomes of these decisions.

Although the specific benefits and limitations of these
different instructional models have not been documented, the
literature does point out videodisc instructional
strategies--common to all three models--which seem to be
especially effective for enhancing motivation and learning.

Many researchers believe that the key advantage of videodisc
for education is its ability to initiate active learning. For
this reason, preferred instructional strategies allow students to
play an acti : role in determining the order of videodisc
presentations in contrast with the passive, linear nature of book
or videotape learning. Branching patterns which provide students
with alternatives and permit self-paced learning are a necessary
prerequisite to active videodisc learning (Currier, 1983). A
high degree of user control, which allows students to regulate
pace and level of instruction, is also a crucial component of
active learning (Kearsley and Frost 1985).

In addition to alternative branching patterns and extensive
user control, researchers also find intriguing and superior
visuals to be critical to active learning with educational
videodiscs. Glenn and Kehrberg (1981) believe that active

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learning results from the interface of "visual presentations that teach, reinforce, and test learning" with computer-generated directives and elicitations. Davis (1984) values the videodisc's ability to present a wide variety of both realistic and hypothetical images. Bunderson, Olson, and Baillo (1981) find videodisc especially effective at presenting hard-to-visualize concepts. And Tobin (1984) concludes that effective educational videodiscs result from the skillful combination of the visuals and the computer-generated information into a "cohesive learning package."

Simulations are viewed as the instructional model most likely to elicit active participation in learning (Kearsley and Frost, 1985). To date, simulations have been designed for a variety of purposes. Kearsley and Frost (1985) note that existing videodiscs are used for science experiments requiring complex and expensive lab equipment, medical diagnosis practice, and management training and sales. Simulations may be particularly successful at teaching difficult processes such as problem solving and decision making and difficult procedures such as CPR (Kearsley and Frost, 1985; Bunderson, et al., 1981). Currier (1983) thinks videodiscs, such as a CPR training disc and an army tank-gunnery simulator, offer a powerful means of simulating emergency situations and providing emergency training without risk to human life.

Simulation videodiscs are believed to increase student

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motivation and initiate active learning in many ways. Lindsey
(1984) reports that student attention can be increased by
integrating "s'ort, provocative questions strategically into the
presentatio. .18). Lind ey also believes that dramatic
tension creates a challenge which leads to motivation and he
advocates presenting a problem and permitting the learner to join
in the resolution. Kearsley and Frost (1985) find that learner
involvement results from making the student a character in the
drama. "Detective strategies" have also been used in discs such
as the "Tacoma Narrows" in which students use information
provided by the videodisc to solve a problem.

Exploration--the open-ended exploration of visual
material--is another instructional strategy incorporated into the
simulation model. One application of the exploration strategy is
surrogate travel or "movie maps" in which locations too far away,
expensive, or dangerous can be visited. The original and most
notable movie map stores thousands of still frame photographs of
the streets of Aspen, Colorado. Currier (1983) explains the
learning potential of this videodisc technique of exploration:
"They take the student directly into an experiential universe
where events unfold realistically; learning is a natural result
of experience" (p.58).

In summary, these studies and others--including those by
Bork (1981), Kearsley (1981), and Currier (1933)--lead us to
hypothesize specific instructional strategies which seem to be

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especially effective for educational videodiscs:

(1) opportunities to engage in active learning by controlling the order of videodisc presentations, choosing alternative learning strategies, and regulating learning pace;

(2) interactive, realistic practice that is based on visual images and includes feedback, guidance, and provocative questions;

(3) presentation of a wide variety of conditions, situations, and variables, both real and hypothetical, including explorations of remote locations and long-term events;

(4) use of highly-produced visual images that are novel, relevant, and/or have dramatic appeal.

While researchers are beginning to identify instructional strategies that result in effective interactive videodiscs for education, no comprehensive studies have been conducted that compare the benefits and drawbacks of these strategies and their applications in a variety of learning contexts. The three currently existing videodisc instructional models--tutorials, visual databases, and simulations--each contain promising instructional strategies. It may be that novel combinations of these strategies will result in new models for effective educational videodiscs. Kearsley and Frost (1985) conclude, "It seems likely that designers will invent new metaphors and models for interactive videodisc as well as adapting other, existing ones" (p.12).

The challenge for the design of educational videodiscs is to

develop appealing and educationally sound ways of presenting
moving video images and illustrative graphics and still frames,
terse explanations and thought-provoking text--woven together in
interactive learning formats that promote active student
learning.

B. Videodiscs and Science Education

Science education introduces new ideas, provides a paradigm
for thinking and analyzing problems, and nurtures curiosity about
the natural world. The videodisc medium's unique strengths--
interaction with and management of audio, visual, and textual
information--and unique applications of instructional strategies,
indicates that it may be ideally suited to the task of science
education. By bringing the natural world into the classroom,
videodiscs offer ways to teach and learn science facts,
processes, and methods that are active and participatory.

Bunderson et al. (1981) summarize the potential of
interactive videodiscs for science education:

> 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. (p.5)

Currently, science videodiscs are largely limited to simulated science laboratories. Although successful in teaching content--information, facts, ideas--and improving science-process skills--proceeding logically, formulating and refuting hypotheses, recording observations, making precise measurements (Bunderson, et al. 1981; Davis, 1984)--lab simulations may be limited to one-time use in many classrooms. Supplementary materials with "evergreen" qualities which add a new dimension to classroom learning rather than serving as substitutes for lab experience may have a greater impact on the nation's science classrooms.

There is a pressing need for innovative, action-oriented, and cost-effective science materials in the nation's secondary school science classrooms. Students in today's secondary schools usually learn science in textbook-structured courses that present current scientific theory and information in a framework built around traditionally- defined science disciplines (Hurd, Bybec, Kahle, and Yager, 1980; NSF, 1981; Yager and Stodghill, 1979). Materials used in the science classroom tend to be uniform in appearance and portray a superficial view of science as facts, verbal abstractions, and lab exercises (Hurd, McConnell, Robinson, and Ross, 1981).

These materials may help students learn the facts and appropriate laboratory procedures, but they rarely allow for a range of learning experiences in a variety of contexts (Hurd,

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1978). They limit science teaching and learning to a routine
process of lecture, assign readings, discuss, and test
supplemented by teacher demonstrations, some lab work, and
occasional educational television viewing. Few opportunities are
provided for developing and honing the skills most essential to
an understanding of science: decision making; problem solving;
creating; observing; and valuing (Hurd, et al., 1981).

There is also a need to improve student attitudes toward
science. The 1976-1977 National Assessment of Educational
Progress documents a trend of declining positive attitudes toward
science among secondary school students. Positive attitudes,
measured by feelings toward science classes and the number of
science-related outside activities, decline with each grade level
and from fall to spring during the academic year (NAEP, 1979).

Problems in science education are not new. Beginning in the
mid-1950s, educators, scientists, and government officials
recognized that if students do not develop basic scientific
skills and positive attitudes toward science, they may never be
equipped to pursue higher education or careers in science. By the
mid-1970s, millions of dollars were spent to improve science
teacher training and upgrade secondary school curricula and
laboratory facilities. The National Science Foundation alone
committed $117 million to 53 curriculum development projects
between 1954 and 1975 (Jackson, 1983).

These instructional materials incorporated a new philosophy

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of science teaching and learning. The conventional approach was to teach science as a body of organized knowledge to be learned by the acquisition of predetermined facts, laws, and theories from a textbook. Developers of the new curricula organized information around concepts and processes that illustrate the unity of the scientific endeavor and are basic to understanding science as a way of knowing. The goal of science education was no longer to teach repeatable knowledge but to provide an environment in which students carry out investigations and make discoveries through the same methods used by scientists. Teaching students "process" skills--ways of thinking about and solving problems scientifically--was of paramount importance. The curricula advocated a multimedia approach; in addition to a student text, films, lab workbooks, teacher guides, film loops, overhead transparencies, and supplementary readers were provided (Dede and Hardin, 1978; Welch, 1979).

Many teachers tried one of the new programs. An NSF-sponsored survey in the late 1970s showed that over half the school districts sampled had adopted at least one of the federally-funded materials for grades 7-12 (Helgeson, Suydam, Blosser, Osborne, and Hose, 1978). Where the new curricula were successfully implemented, they had positive effects on student attitudes and achievement.

When compared to students taught by traditional materials, students studying the new curricula showed a greater

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understanding of science subject matter and the processes of science. They also had more positive attitudes toward science, developed more sophisticated problem solving and critical thinking skills, and acquired specific skills related to scientific methods (Johnson, Ryan, and Schroeder, 1974; Welch, 1979; Kyle, Shymansky, and Alport, 1982; Weinstein, Boulanger, and Walberg, 1982).

The goals of the new curricula have not been invalidated. Indeed, many of the new science materials and teaching methods have been incorporated into the theoretical conventions of science education. However, few reforms or substantive changes in practice have "trickled down" into the nation'_ science classrooms (NAEP, 1975).

Budget cuts, declining enrollments, inflation, back-to-basic movements that exclude science, and the conservatism of school districts have slowed the adoption of new curricula in recent years (Welch, 1979; Jones, 1981). Resistance among teachers to the demands of teaching with discovery-oriented materials may also contribute to the trend toward more traditional curricula. The net effect is that most science classrooms today are little different from those of twenty years ago (Stake and Easley, 1978) and the problem of passive science curriculum materials is still with us. Interactive videodiscs, particularly when incorporating the discovery approach, may serve science education as effective forms of curriculum enrichment.

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THE RESEARCH PLAN

The discovery approach, with its emphasis on experiential and
multimedia explorations through scientific modes of inquiry, is
an important model for science education and one that is
consistent with the strengths of videodisc as a teaching tool.
We decided to explore whether discovery-oriented videodiscs could
serve as enriching supplementary resources in science classrooms.
We addressed this research goal by creating a discovery-oriented
videodisc.

A. The Research Videodisc

Two general principles guided our early thoughts about the
research videodisc. First, we knew our aim was <u>not</u> to
produce a commercially viable videodisc. Instead, we wanted the
research disc to serve as a tool for exploratory research into
the effectiveness of the videodisc medium for presenting a
discovery approach to science. Second, given our limited
financial resources, the research videodisc had to be created as
inexpensively as possible.

Creating a videodisc, even one without commercial value,
involves producing video images or using existing video images.
It also involves programming videodisc software. Producing
original video and programming video software are prohibitively
expensive for a noncommercial project. Members of our project

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group represented ETC consortium member organizations that together offered a less expensive alternative.

The WGBH Educational Foundation of Boston and the Children's Television Workshop of New York City were willing to let us select video clips from existing television programs for the research videodisc. Both organizations produce extremely successful, high-quality science television programming for national broadcast: NOVA and 3-2-1 CONTACT respectively. Interactive Training Systems, Inc. of Cambridge, Massachusetts, another ETC consortium member organization, offered us a videodisc authoring system, Authority (TM), used to develop custom interactive videodiscs for sales and corporate training. Descriptions of the television programs and the authoring system are included in Appendix B. The "retrofitting" of existing video and use of an established authoring system would permit the creation of a research videodisc and attain project a ms within our restricted budget.

B. Research Questions

Once the decision was made to create the research videodisc through retrofitting, we formed specific research questions and devised a research plan. The research questions are:

(1) What are the design choices and compromises involving video resources, an authoring system, and instructional strategies when existing science television science programs are retrofitted for the research videodisc using an authoring system?

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(2) What affective and cognitive student responses are associated with the research videodisc's visual and audio presentation and interactive formats? What are the associations between these responses and student attitudes towards science and their applications of scientific methods?

(3) What kinds of videodisc use patterns and user-machine interactions--including student interactions with the videodisc and student interactions with each other or a teacher--occur during videodisc use? Are any particular use patterns or interactions associated with student applications of scientific methods?

C. Addressing the Research Questions

We carried out the research by giving the videodisc certain characteristics. To employ the discovery model, the videodisc needed to present science information in ways that demand the practice of science-process skills by means of different kinds of interactions. By explicitly focusing on the process of doing science rather than on the factual knowledge resulting from scientific endeavors, features unique to videodisc medium could be called upon to set up interactive and experimental situations that would hone the process skills of users. The research videodisc must take on a number of roles--information provider, database recorder and illustrator, problem poser, game partner, teacher, simulator, and tool--to provide a rich learning environment for the practice of science-process skills.

In order to evaluate which instructional features and interactive formats are successful for teaching within the discovery approach, we decided the research videodisc should be an instructional design sampler. As a design sampler, the disc could showcase a range of instructional strategies such as

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experiments or open-ended explorations of visually illustrated phenomena. Each strategy could foster different kinds of presention and interactive formats which would be incorporated into each of several separate lessons. This would give the disc the design balance and variety necessary to address our second and third research questions.

We also considered the mood or affective state to be created by the research videodisc. We wanted the disc to be appealing and relatively playful in tone but serious in intent. We would give the disc educational value and worthiness without making its use a chore.

With these plans defined, design and development of the research videodisc commenced. Middle school students were chosen as our target audience because NOVA and 3-2-1 CONTACT viewerships overlap at this age group and middle school curricula cover a range of science subjects treated by these television shows.

At this writing, the design and development of the research videodisc is complete. Videodisc production and authoring will occur during fall, 1985. Research and evaluation of the videodisc will begin during the last months of 1985 and continue through summer, 1986.

The process of designing and developi ₆ the disc over the last year has clearly delimited the potentials and constraints of videodisc creation through retrofitting. These potentials and constraints, and our conclusions regarding the process of

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videodisc retrofitting, are described in the next section of this report.

The discussion of our findings on the second and third research questions will make up our next report.

RESULTS AND DISCUSSION

Designing and developing the research videodisc was a complex
and iterative process that required a team effort over many
months. Researchers, educators, teachers, writers, video
producers, and professional course developers met monthly; a core
group made up of WGBH and CTW staffers and teacher advisors met
as often as three times a week.

We report our findings on the creation of the research
videodisc in two parts. The first part describes how we designed
and developed the disc. It speaks more to the process than to
the outcome. The second part describes the final design for the
disc resulting from the development process.

A. Development of the Research Videodisc

Designing and developing the research videodisc involved
several tasks: 1) reviewing the video resources and selecting
specific video segments; 2) choosing a videodisc theme;   3)
learning the capabilities of the authoring system;   4)
identifying discovery-oriented instructional strategies that take
advantage of the videodisc medium; and 5) creating lesson plans.

A lesson plan is a flow chart description of one
self-contained portion of the research videodisc. It is the step
in the design and development process that directly precedes
preparations for production and authoring. With an instructional

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design sampler, we set out to devise several lessons.

While completing lesson plans was clearly the goal of our design and development effort, the other tasks listed above were not carried out in linear progression. They represent clusters cf overlapping activities, pursued concurrently, from which the lesson plans slowly emerged. Lesson plan development involved the careful consideration of video resources, authoring system capabilities, instructional strategies, and the disc theme.

The design and development process was greatly influenced by the interaction of three "givens" in our research plan: the derivation of video images from existing television programs; the use of an authoring system; and the adoption of the discovery approach. Each of these factors presented different potentials and constraints; realizing potentials and working around constraints was our guiding design principle. Although pedagogical orientation and authoring system capabilities had a great impact on design and development, the nature of the video turned out to be the controlling factor.

1. The Video Resources and Selection Criteria

An initial screening of the television programs served to survey the video resources and define the kinds of visual images that would be most appropriate for inclusion on the research disc. A review of 6 seasons of NOVA and 4 seasons of 3-2-1 CONTACT resulted in an initial selection of 12 NOVA programs and

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42 3-2-1 CONTACT programs. A checklist of criteria for choosing

video segments was develope' to assist in the selection process.

Ideally, to be considered for inclusion on the research disc, we

felt video segments needed the following characteristics:

1. Visual and/or dramatic appeal. Visual appeal means
something observable happens, including phenomena not readily
observed or experienced in real life, such as events in exotic
places; close-up views and other alterations in perspective,
including video images in which time is collapsed or expanded.
Dramatic appeal means having a storyline and characters with
which students can become involved.

2. Manipulation appeal. Phenomena or events which have
features and variables that can be investigated with a variety of
outcomes or are amenable to replay or alterations in speed or
direction.

3. Comprehensiveness. Sufficient material for a full visual
treatment of a concept or topic, including background information
and explanations.

4. Curricular fit. Concepts, topics, or phenomena relevant
to the curricula to be supplemented--in our case, standard
middle school science programs.

Subsequent iewings of the television programs helped us

evaluate and select the most promising visuals for presentation

in a discovery approach. NOVA and 3-2-1 CONTACT offered

different advantages and disadvantages. While both series

address topics relevant to middle school science curricula,

finding visuals that met our four selection criteria was a

difficult 'ask.

NOVA programs, as hour-long documentaries, offered several

promising investigations of animal behavior, ecology, earth

history, and astronomy. We were particularly captivated by a show on a relatively new theory of cretaceous extinctions ("The Asteroid and the Dinosaur") and another on human and animal survival techniques ("Living Machines"). These scientific discovery stories, however, were like many of our favorite NOVAs. They developed over a full hour of video time and often included lengthy interviews with scientists and other visually unintriguing segments. Often a scientist was shown talking about a phenomenon without a presentation of the phenomenon itself. So we began looking for stories inside of stories: discrete, interesting, and visually illustrated problems that could be fully addressed with 5-10 minutes of appealing video edited from the full-length program.

3-2-1 CONTACT programs, as magazine shows with short 30-second to 5-minute segments, offered several promising stories about technology, medicine, animal behavior, weather, and geology. We particularly liked segments about wind and animal location, but the visuals did not suit our needs. Many of the most interesting 3-2-i CONTACT pieces were produced as brief introductions or overviews of scientific concepts and issues; if they had visual or dramatic appeal, they often lacked comprehensiveness and manipulative appeal. We looked for longer stories or groups of shorter stories with similar content. As we viewed video segments, we thought about a videodisc theme.

2. The Videodisc Theme

Initially we believed that a discovery appproach would work best in the videodisc medium when matched with a content or a concept theme. This would give the research disc a clearly distinguishable and unified purpose, such as "to teach students about animal behavior" or "to teach students about the concepts of mass and volume." We considered images on specific subjects suggested by the visuals, such as "volcanos." We also examined how well the visuals portrayed generic science concepts, such as "complex systems" and "heat and temperature," named as ETC targets of difficulty.

Preliminary screenings of NOVA and 3-2-1 CONTACT programs revealed, however, that a skill-related theme offered better opportunities to exploit video resources. The video resources, although rich, could not be stretched to cover a single concept theme. Since imposing a concept theme on the visuals did not work, we looked for themes suggested by the visuals. This effort proved equally unsuccessful; the visuals were simply too content poor. Finally we realized that the video segments which fulfilled our selection criteria, regardless of content, could be molded--through editing and integration with computer-generated material--into lessons that taught science-process skills. We decided to make "scientific modes of _nquiry" our disc theme.

We defined our theme as the ways scientists investigate the

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natural world, including the gathering and organization of data, the construction of explanatory principles to account for observations, the formulation and testing hypotheses, and the making of models, inferences, and predictions. Content, while important, would be a vehicle for illustrating and eliciting the process of science. Each lesson would pose a key question or problem which students would study by exercising process skills. With this decision, the discovery approach and the disc theme became one and the same--the disc became an environment for learning science-process skills.

In the final stage of video selection, after deciding to make "scientific modes of inquiry" the focus of the research disc, we narrowed our search to visuals that illustrated or elicited skills related to the scientific method. We included any subject matter as long as it was appropriate for middle school students.

3. The Authoring Software

The authoring software was the other unknown to be explored by the core group. Those group members most actively involved in the design of the research videodisc had to understand the system's features and functions so that lesson plans could be created using selected video segments in ways which exploited the interactive capabilities of the technology.

The core group started by examining finished videodisc

courses produced at Interactive Training Systems (ITS) for corporate clients. Looking at finished products gave us an idea of what had been done in the past and what, very generally, our disc would look like. The ITS members of the project group shared design guidelines. We found out about user input and video handling, branching between screens and other navigational issues, amount of text per screen and other issues related to screen displays, record-keeping, and graphics.

The ITS authoring system permits interaction with users in the form of touch screen or keyboard input: no screen should have more than ten touch-sensitive areas; keyboard input requires e ensive error trapping but it is best to limit answer permutations to twelve alternatives. Users are permitted to replay video, but not frame-by-frame. Freeze frames or video stills can be made from any video image. All moving video has two audio tracks: one can be used for narration or instructions, the other can be used for music. Additional features, such as replaying video backward, are created with video postproduction techniques.

Users should be able to easily navigate through the research videodisc: the top and bottom lines of every screen would be reserved for directions and command line information; complex branching patterns are possible but not recommended; menus should be no more than three levels deep. Information, whether graphic or textual, should be easily read from screen displays. A

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40-column display, for example, limits text to 8-10 lines. Too
many computer-generated colors on a screen are distracting. The
system can keep track of a user's progress and record and display
user choices and other forms of input. The system is not capable
of detailed or animated graphics. Self-contained computer
programs, such as for computer games, can be added.

With a working knowledge of the authoring system and with
promising video segments identified, we began to think about
imaginative, discovery-oriented applications in preparation for
creating lesson plans.

4. Instructional Strategies

Specific instructional strategies were needed to serve as
foundations for lesson plans. These strategies had to suit both
the videodisc medium and our chosen pedagogical orientation.

Videodisc is a unique medium characterized by a new
combination of capabilities. While we recognized from our review
of the literature that tutorials, visual databases, and
simulations may be instructional models for the technology, we
felt that videodisc instruction may require new instructional
methods. These methods may be new conceptions as well as
extensions and adaptations of models derived from video and
microcomputer software. In addition to reviewing the
instructional strategies suggested by the research literature,
the core group discussed what video and microcomputers do best.

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Educational video or television and microcomputers have different but complementary pedagogical strengths that are combined in videodisc technology. Television is a powerful and dynamic medium for presenting ideas, influencing learning and cognitive processes, bringing the "real" world directly to the learner, and portraying much of the color, excitement, and immediacy of actual experiences. By its nature, however, video cannot provide opportunities for interaction because its visual images are designed for uninterrupted linear viewing. The microcomputer, on the other hand, promotes interaction and provides immediate feedback. In addition, it can store and retrieve vast amounts of data. The computer, however, lacks the capability to display real-life moving visual images.

We found the unique instructional feature of the videodisc medium to be the variety of presentation and interaction formats made possible by the linking of software and video. Video can be used to introduce a topic, set up a problem, provide data to be observed and charted, illustrate a method or process, make a transition to another topic, or serve as a reward for a correct solution to a problem. While the computer must be used to present the network of menus an other text screens that links all video and other displays, software can also be used to manipulate video action, generate text, create graphics including maps and graphs, and highlight or alter video displays through screen overlays and other devices.

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In addition to new instructional opportunities offered by the medium, we consid red our pedagogical orientation: the discovery approach. The discovery approach to science education views science as a human undertaking, a process of seeking an understanding of the natural world. We wanted to find ways to involve students in ways of thinking scientifically. The research disc should encourage observing, measuring, organizing and interpreting data, inferring, predicting, formulating hypotheses, and generating models to explain data.

With this ideal in mind, we brainstormed about the best ways of getting middle school students to explore ideas, test theories, and raise questions. We decided that the research videodisc should incorporate instructional methods that permit students as much hands-on activity as possible. Students should, for example, have opportunities to conduct experiments by manipulating variables, making observations, and recording results. They should also explore phenomena, develop explanatory hypotheses, and then apply them.

Project group members preferred more open-ended and self-paced instructional designs, but the research videodisc had to contain at least one example of a more structured approach to be a design sampler. We explored the advantages and disadvantages of certain learning aids including mandatory branching patterns, tests, and help and reward screens. We agreed that the lessons should include a mix of these features.

We also determined that all disc activities should stand alone—they could be carried out by students working alone or in groups, with or without teacher direction. Students would be able to complete an activity within 30 minutes.

We also thought about instructional strategies in terms of the sources of the video and total video time. With a limit of 30 minutes of total video time, we wanted the lessons to have approximately the same amount of motion video orginating in equal portions from NOVA and 3-2-1 CONTACT. Reserving two minutes for a video leader that would display a title and credits left 28 minutes of video time for the five lessons. Judging from the fact that suitable video images were limited in quantity, we decided that it was impractical to plan for the lessons to have equal amounts of moving video. For the same reason, we decided to mix segments of NOVA and 3-2-1 CONTACT video within the same lesson when appropriate instead of establishing lessons with exclusively NOVA and 3-2-1 CONTACT visuals. We eventually selected a number of video segments from which we decided to build five separate lessons.

5. Lesson Plans

Plans for the lessons evolved slowly. We worked back and forth between intriguing video images and instructional strategies, between authoring system capabilities and notions of the disc as a whole. A loose pattern of lesson plan development

emerged as the lessons took form.

Lesson plans always grew out of video resources. Video images were lesson building blocks, the authoring system created the computer-generated formats that would act as supporting beams and mortar. The discovery approach and the instructional strategies were the principles that guided our conceptualization and subsequent construction of each lesson.

The NOVA program "The Green Machine," for example, included segments showing how plants respond to changes in the placement an color of light and what happens to the plant's ability to sense light when different parts of a shoot are covered or cut. The visuals were comprehensive enough to introduce a problem (How do plants respond to light?) and construct a laboratory-like experiment in which students manipulate independent variables and view and chart the resulting effects.

Working from selected visuals and the concept for an experiment-like design, we determined which science-process skills we wanted the lesson to teach and how. Interactions within and flow between text screens and video segments were worked out according to the features and functions of the authoring system: menu options, transitions, paths between text screens and visuals were determined; presentations including layouts and the kinds (touch screen or keyboard entry) and timing of interactions for all screens and scenes were designed. This process was repeated for all of the lessons. The video for the

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PLANT GROWTH experiment had to be edited into small clips and a narration for the introduction would have to be written, but the lesson plan was completed without difficulty.

The remaining four lesson plans required repeated design revision. It was extraordinarily difficult to mold existing visuals and the content they illustrate in ways that would not only sharpen the science-process skills of users but also take full advantage of the medium.

Teaching Science-Process Skills Using Existing Video:

Integrating chosen visuals into interactive learning formats that would illustrate or elicit science-process skills was a constant stumbling block to lesson development. For one lesson in particular, VISIBLE HEAT, this problem was nearly insurmountable.

VISIBLE HEAT began as a lesson about volcanoes. Its primary video material was taken from several 3-2-1 CONTACT shows that document a teenager's exploration of an erupting volcano in Hawaii. Accompanied by a scientist, the teenager takes lava samples and measures the temperature of a lava flow. The visual images were dramatic and told a story, but they were not comprehensive enough in content to support a lesson about the eruption of volcanoes in general or the behavior of lava in particular. Nor did they contain manipulatives. Determining a central question or problem was impossible until we broadened the

scope of the lesson from the topic of volcanoes to the concept of a relationship, illustrated by lava, between color and temperature. The volcano video became a hook and set up for a lesson that poses the question: Are color and temperature related?

Once we agreed on this approach, we had to reconsider our video resources and our target users. Our target users were middle school students who we felt had an intuitive sense of the relationship between color and temperature. We thought we could use this familiarity with the content to our advantage. Students might be motivated to think about the process of discovery if they already had an inkling about what would be found. So we decided to design a very structured lesson that explicitly guided students through the process of forming, articulating, and refining an hypothesis.

This instructional method and objective, however, required additional video. Examples of materials other than lava that reveal changes in color and temperature were needed for an observation stage prior to the formulation and articulation of the hypothesis. We searched our video resources and found visuals of glass blowing and iron working that showed these materials at various temperatures. Similarly, we sought and found visuals for the hypothesis refinement stage. These visuals had to include examples of materials for which the hypothesis would not apply. We wanted students to refine their hypotheses

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by defining the conditions under which color and temperature are related.

Expectations about the Videodisc Medium and Authoring System:

Often the _exact_ instructional strategy envisioned by the core group for a lesson could not implemented. This was most often due to impossible expectations about the videodisc medium. Frequently, however, a misunderstanding of the capabilities of the authoring system led us astray. We rarely gave up an idea, however. We usually scaled it down or otherwise modified it in a way that could be constructed by the authoring system without compromising its pedagogical integrity. While the problem of mismatched expectations and actual system capabilities arose to some extent in nearly every lesson, it was especially troublesome during the development of the lesson plan for ANIMAL DISGUISES.

ANIMAL DISGUISES originated with video from the NOVA program entitled "Animal Imposters" and posed the question: How do animals disguise themselves? We had no difficulty developing two playful observation exercises in which students must find or identify "hidden" animals. But the substance of the lesson was to be an open-ended pattern-seeking and classification activity in which students observe twelve video clips of various animals and then devise and label categories in order to group them by type of disguise.

Our original plan was to have students establish video

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"drawers" in which they could save and collect video clips they thought illustrated the same type of disguise. Each drawer represented one category. Students could view the contents of any drawer at any time and move clips from one drawer to another as they considered and reconsidered their categories. The last step was to articulate the internal inferences they had made about the clips by naming their categories. This was to be accomplished by typing in labels for the drawers. One way of classifying the clips and an explanation for this scheme was offered at the end of the lesson.

These video handling and category naming aspects of the design could not be created with the authoring system without the addition of an expensive custom program. Unwilling to give up the classification idea, we modified the activity so that students could sort the clips into three groups and then label the groups choosing from a list of possibilities. Even this version posed too many authoring problems and we felt the discovery approach was too diminished.

In the end, the core group worked out a design that resembled the original plan. We simply took those tasks the system could not handle well--keeping track of several groups of video and recording category names--and asked students to create a chart using pencil and paper that does the job perfectly. We also improved the design by having students create their categories after viewing just six representative clips.

Observation of the animal disguises in the other six clips serves as a test of their categories.

Making Existing Video Interactive:

We often found ourselves trying to make the best use of a video segment which, although strong in one or two of our selection criteria, was weak in the other dimensions we deemed critical for successful videodisc retrofitting. We rarely had the luxury of working with video that fulfilled all four of our selection criteria. The lesson WHAT'S IN THE BOX? illustrates what happens when a lesson is planned from a weak video segment, in terms of our videodisc selection criteria.

The lesson WHAT'S IN THE BOX? is built around a 3-2-1 CONTACT profile of Nobel laureate Linus Pauling. The video segment shows Dr. Pauling as he deduces from audio clues the shape of a wooden block hidden inside a small cardboard box. We thought that this clip could serve as an interesting model for how a scientist solves a problem. We liked the human side of the story and thought students might be intrigued with Pauling's method and quick success.

Observing his method requires viewing the linear video segment at least once. It is five minutes long. After watching the segment it might not be clear to viewers exactly what took place. Although the video clearly portrays how he solves the problem, Pauling does not say what assumptions he makes about

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angles and sides and why he follows specific avenues of
investigation. As a "talking head" segment, the video not only
lacked visual appeal but also was not comprehensive in revealing
either his method or the relatively sophisticated geometry that
underlies his method. The segment also lacked manipulation
appeal. There were no visuals to serve as illustrations for
different experimental situations involving the box and various
objects.

We soon found ourselves bogged down with writing "thought
balloons" to explain Pauling's unspoken thoughts and designing a
game that simulated the mystery block problem. After many
unsuccessful attempts to conceive of a simple game that used
animated computer graphics, we came to the startling realization
that students would learn far more from such a game if they
played it using a real cardboard box and a collection of blocks.
We had been trying to use the videodisc medium to teach something
that was better learned using traditional manipulatives in the
classroom.

We were about to discontinue work on the lesson when we
realized that what Pauling was modeling could be viewed in a
larger context. The block in the box was only an example of how
scientists find out about things they cannot directly observe.
The lesson did not have to be focused on blocks and their
geometric attributes. The thought balloons became focused on
Pauling's process of investigation--his way of forming a

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hypothesis, testing it through experimentation, and when an experiment proved it wrong, forming a new hypothesis. A computer game, programmed by a private educational software developer, was acquired to give students a chance to apply this scientific method to a similar problem.

6. Conclusions

The plan to retrofit existing video for the research videodisc meant that no expensive video production costs would be incurred; all the video images would be derived from e. sting resources. Use of an authoring system offered a cost-effective and relatively fast way to program the disc software.

For both the video and the software, the trade-off for the savings of time and money was having to develop lessons within established parameters. Design work could not progress from an ideal concept to a concrete realization. Instead, we started with the concrete--visual images from science television programs--and fashioned these images into lessons in the best ways offered by the authoring system that suited our instructional strategies and videodisc theme.

We found that this process usually limited the use of video segments to visual databases for illustrating content. This is because, according to our video selection criteria, the kinds of visuals that may take advantage of the videodisc medium are not readily available from conventional video resources including

NOVA and 3-2-1 CONTACT, the two most highly acclaimed science television series of this decade. Without a large degree of visual and manipulation appeal in particular, video designed for linear viewing may preclude videodisc instructional strategies that use visuals for simulations and new applications unique to the videodisc medium.

The content or subject of the video images affects the retrofitting process as much as the nature of the video images. Existing video already has visual subjects and content, carefully taped and edited to suit a narrow purpose. Although new narration can be written, use of existing video requires acceptance of established visual images. Rarely can these images be made to fit anot er use in the same or a different medium. With visual images predetermined in subject and scope, retrofitted videodiscs are perhaps more appropriate for teaching skills th   ecific subject matter.

The de   and development process for the research videodisc began with, and repeatedly returned to, the video resources. Our experience with the process of retrofitting leads us to conclude that the overriding influence of video resources is a serious design concern for the creation of retrofitted videodiscs regardless of subject area, instructional approach, or means of programming. However, we recognize that designing and then programming the research videodisc from scratch may have proved equally difficult but for different reasons. Both means of disc

creation present disc designers with challenges.

Although the process of retrofitting was
arduous, intensive designing and redesigning assured that
existing visuals were integrated with computer-generated
interactions in ways that met our design objectives. In the next
phase of this research project, testing of the research videodisc
will determine the success of the different videodisc
presentations and interactions for eliciting science-process
skills among middle school students. Plans for researching the
videodisc are described in the last section of this report.

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B. Description of the Research Videodisc

Five lessons resulted from the design and development process. They are summarized below. The summaries cannot capture the interactive nature of the lessons, but they adequately portray the objective of each lesson and what happens when lesson use progresses in a relatively linear fashion.

1. PLANT GROWTH

This lesson is composed of several related activities that promote increasingly sophisticated ways of thinking about a single question: How do plants respond to light? The activities include an introduction to the role of light in plant growth, three experiments designed to lead students to formulate and test hypotheses about the interaction of light and plants, and a prediction quiz. The lesson is designed to give students practice in identifying variables, conducting controlled experiments, making and recording observations, and forming predictions. Modes of interactivity include altering variables, replaying video to observe events more than once, and recording data on a chart.

The short video introduction provides background information and briefly explores issues related to each of the experiments. The introduction is modular in design. When viewed all at once, the modules form a comprehensive overview of the lesson. Individual modules also serve as brief set ups for each experiment.

The experiments are short simulations of how different aspects of the relationship between light and plant growth might be investigated in a laboratory setting. At the start of each experiment, students are given a statement regarding a phenomenon about which they are asked to form an hypothesis. Students test the hypothesis in a controlled experiment using independent and dependent variables; students manipulate an independent variable and observe changes in a dependent variable illustrated in moving video. During every experiment, students record their observations on a computer-generated chart using the touch screen feature.

The first experiment asks students to form an hypothesis on how a plant's growth is affected by the position of a light source. Students then test their hypothesis by altering the position of the sun and observing the reaction of growing plants. Plants always grow in the direction of a light source regardless

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of its position.

The second experiment asks students to form an hypothesis on where plants sense light. Students test their hypothesis by covering or cutting plant parts and observing subsequent plant growth. Plant growth is normal when the stem is covered but is nonexistent when the tip is cut or covered.

The third experiment asks students to form an hypothesis on how plant growth is affected by the color of light. Students test their hypothesis by altering the color of light and observing the reaction of three plants over the same period of time. Plant growth is normal in red light and slowed in green and blue light.

The prediction quiz asks students to apply their new knowledge by predicting the outcome of several "what if" questions. The questions combine two or three variables introduced in the experiments. One question might be: How would a plant grow in green light if its tip is covered? The data charts created by students during each of the experiments may be viewed at any time during the quiz.

2. ANIMAL DISGUISES

This lesson consists of four activities that promote the formation of hypotheses from observations of camouflage and mimicry in the animal world. The activities include an introduction to animal disguises, a sorting exercise in which students identify different classifications of animal disguises, and two observation games.

Critical observation and the subsequent formation of hypotheses is the process skill emphasis of this lesson. The classification exercise uses video clips to furnish observable data in which students seek patterns. To successfully complete the exercise, students form hypotheses to be tested, revised, and extended. Interactivity includes playing and replaying the clips, recording observations using pencil and paper, and group discussion of the process and result. The games encourage trial and error experimentation while taking full advantage of the technology's ability to produce appealing touch-screen interactions.

The video introduction illustrates cases of camouflage and mimicry among animals and describes them as strategies used by species to aid in survival. The purpose of the introduction is to provide a lesson overview.

In the classification exercise, students observe twelve video clips of animal behavior and sort the clips by the form of mimicry illustrated. Students are told that the clips depict three forms of mimicry but not what the forms are; students must seek patterns and form internal hypotheses to guide their sorting activity. Optional thought questions are available to help students think critically about what they are viewing. Students may view the clips as many times as they choose.

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Students group the clips by filling out a sample two or three-column chart copied from a screen at the start of the exercise using pencil and paper. After they have viewed and sorted the first six clips, students will label the categories based on the commonalities that led them to group similar clips. As a test of their classification system, students then view the next six clips. After all twelve clips have been sorted, students may view a completed chart portraying one way to classify the clips and choose to see the clips again. This time similar clips are grouped together according to the classification scheme presented. In this final viewing, the clips are accompanied by explanations of the distinguishing features of three forms of mimicry. A screen containing several discussion questions related to the role and significance of classification schemes is available at the end of this exercise.

The observation games are playful approaches to the identification of hidden animals. In the first game, students touch the screen to reveal portions of a scene containing an animal hidden behind an opaque overlay. The overlay can only be lifted one piece at a time. The animals are not camouflaged in their environment but are difficult to identify because only a fraction of the scene is revealed momentarily. The second game introduces the phenomenon of cryptic mimicry by challenging students to find and touch camouflaged animals.

3. SEEING THE UNSEEN

This lesson is open-ended and exploratory in nature. It includes an introduction to high-speed motion pictures and two exercises designed to promote the generation of hypotheses from observations of phenomena that are not discernable to the unaided eye. The lesson content focuses on the question: What does altering the perception of time reveal about the nature of everyday events?

The introduction discusses how the perception of observable events is dependent on the speed with which our eyes and brain can process visual information. Time is a subjective frame of reference that can be altered using technology. When an event is filmed at a high speed using a strobe light and the film is later projected at regular speed, time appears slowed down and the previously unseen becomes observable.

The exercises give students opportunities to investigate the meaning of time and ask questions about the sequences and characteristics of actions that make up everyday events, such as a bottle breaking on the ground or a cup of milk spilling over a table top. In the first exercise, students view five events filmed at both regular and high speeds including a hummingbird flying, a deck of cards flying, and popcorn popping. Students can play and replay each event to study and compare what new information is revealed when the same action is viewed at different speeds. Thought questions guide students to form

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hypotheses about the relationships between time and motion that can be tested using the video clips.

In the second exercise, students play and replay, both forwards and backwards, high-speed films of milk dripping from a container to a cup and water drops falling into a pond. The milk and water drops are two models of the same phenomenon. Thought questions encourage students to look for patterns that permit them to make hypotheses about the physics of liquids in motion. While the milk drop clip is for observation only, a narrative explanation accompanie- the water drop clip.

The lesson can be enjoyed by students working alone or in small groups without teacher supervision, but it is designed to be initially directed by a teacher in a classroom and used as a springboard for discussions. The video images can be explored at several levels and for this reason students and teachers may return to the lesson many times.

4. VISIBLE TEMPERATURE

This lesson guides students through the process of developing, stating, and refining a hypothesis on the relationship between color and temperature. Designed as a structured tutorial, the lesson moves forward step-by-step building from observations to stated hypotheses. Dramatic video clips filmed in exotic locations engage students in ministories and provide the visual database for making observations.

The lesson opens in Hawaii where a young student and a female scientist are exploring the slopes of Mauna Loa, an active volcano. They measure the temperature of lava and take a lava sample, visually introducing a connection between temperature and color. After viewing the volcano sequence, students are presented with a text screen.

The text screen reviews how scientists arrive at scientific knowledge through a process that includes observing related phonomena for patterns, forming and stating an hypothesis, and then testing and refining the hypothesis. It then asks students to investigate the question, "Are temperature and color related?"

The first step in the investigation is observing related phenomena. Students must choose to view at least one of three video clips that illustrate color and temperature changes in lava, glass, and iron. The "lava" clip replays a portion of the opening clip. The "glass" clip portrays a visit to a glass blower's workshop. The "iron" clip documents the making of a ceremonial knife in Malaysia. Each clip contains characters with which students can identify and gives students a chance to role play in a situation and setting that few people experience in real life.

After making observations, students can generalize from lava to the other materials and build a color bar that graphically illustrates how color and temperature are related. They are then prompted to type in an hypothesis that explains the observed

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relationship, such as "changes in color reveal changes in temperature" or "yellow is hotter than red." Before commiting themselves to their hypothesis, students have the option of seeing a list of hypotheses entered by other students. When students are satisfied with their hypothesis, they must pick from a list of hypotheses the one that most captures the meaning of the one they typed in. Students are then told whether they have correctly formulated an hypothesis about the relationship between color and temperature. Those students who want to reform and restate their h,; :heses are told to review the observation clips.

When students have correctly stated a hypothesis about color and temperature, they move to the next step: testing the hypothesis. In the testing step, studer s view a series of video stills each depicting an object that may or may not fit the observed pattern that led to the formation of the hypothesis. For each still, students must indicate whether their hypothesis can embrace these new situations. At the end of this step, students are shown a screen that summarizes how they felt their hypothesis fared. Students may then choose to view the observation clips again or go to the next step: refining the hypothesis.

In the hypothesis refining step, students are presented with thought questions to help them think about the cases that do not fit their hypothesis. They are then prompted to type in a refinement of their hypothesis. Refinements will spell out the conditions under which their hypothesis holds true, such as "changes in color reveal changes in temperature for materials that are solid when cool and radiate energy." Once again students must then pick from a list of hypotheses the one that most captures the meaning of the one they typed in. Students have the option of seeing a list of hypotheses entered by other students before the correct refinement is revealed. An explanation screen is provided.

5. WHAT'S IN THE BOX?

This lesson is designed to show how scientists study phenomena that cannot be readily observed. The lesson shows Dr. Linus Pauling figuring out the shape of a three-dimensional block hidden inside a small covered box and then invites students to solve a similar problem in a computer game. The process of approaching a "hidden" phenomenon or problem, making indirect but systematic observations, and reasoning logically about these observations to reach a conclusion is the focus of this lesson. The lesson is divided into two major sections.

In the first section, Linus Pauling studies something that he cannot observe, a hidden block. A video clip shows the scientist thinking out loud as he determines the shape of a mystery block. The video clip is supplemented with thought balloons that elucidate Pauling's method by describing his assumptions,

providing facts and background information, and illustrating how one shape and then others are eliminated one after another. Viewed together, the video and thought balloons provide a model for how to find out about what cannot be observed.

The second section of the lesson is designed to interest students in solving a similar problem. In a computer game, one to seven mirrors are positioned in a covered box. Students are asked to determine the locations and orientations of the mirrors. To discover the mirrors, students move a flashlight along the four sides of the box and flash light beams inside the box. The way light beams shine through the box indicates mirror characteristics. Based on this observable feedback, students form and test hypotheses about mirror placement.

An experimental mode is offered to students before playing the game. They can place mirrors in the box, flash a light beam, and see the results. This feature allows students to learn the properties of the mirrors and how different paths of light beams are created according to the positions of mirrors in the box. Giving students the opportunity to interact with hidden mirrors will help them transfer their understanding of the processes involved in scientific investigation.

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NEXT STEPS AND FUTURE RESEARCH

Over the next year, the research videodisc will be produced and then evaluated. Production involves pressing audio and video images on a videodisc and authoring the videodisc software. Testing and evaluation with middle school students and teachers will begin after the disc is completed.

A. Production

Production activities will result in the finished research videodisc. The activities include video production, video postproduction, authoring, and quality control testing. These production tasks build directly from the flow charts and production plan constructed during the design stage; production is essentially the technical implementation of the design. Although some design issues will arise during production, they will be relatively narrow in scope and significance.

Video production and postproduction involves preparing all video and audio information to be contained on the research videodisc. When postproduction is complete, a mastering facility will create a master disc template from the master videotape and press a disc.

The computer-generated features of the research videodisc will be authored by ITS using its videodisc software program. Authoring involves linking the complete disc's audio and visual

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data to a computer program. As with other level 3 videodiscs (see Appendix A), access to and from the images and audio on the final disc will be directed by software running on a computer that is joined to the videodisc player by means of a hardware interface. While this authoring process imposes an overall structure on the visual and audio information contained on the completed disc, the disc itself is not altered.

When authoring is completed, the research videodisc will be tested for authoring errors on the ITS system. The testing cycle will result in a disc that is ready for research and evaluation.

B. Reasearch And Evaluation

Our research for next year will focus on investigating
student and teacher use of the research videodisc in both
laboratory and classroom settings. The research will be
exploratory and depend on the observation, recording, and
analysis of what actually transpires when children are exposed to
the research videodisc. Our research plan includes the following
activities:

(1) Preliminary observations of both individuals and small
groups of middle school students will be conducted during use of
the research videodisc. The observations will focus on the
appeal of different interaction and presentation formats, the
kinds of scientific methods elicited by the videodisc lesson
activities, and the variety of interactions and use patterns that
take place.

(2) Based on these preliminary observations, a research study
using more structured observations and interviews will be
designed and conducted. This study will describe more precisely
student responses, interactions, and use patterns associated with
particular videodisc presentation and interactive formats.

Our research will begin with observations of a small number

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of individuals and groups in a laboratory setting and in several
classrooms. The sample will consist of students in grades 6-9
and their teachers. A variety of quantative and qualitative
measures will be developed. The instruments may include pre-use
and post-use tests structured observations, and individual and
small group discussions. Data analyses will aim to describe any
patterns evident in student responses, interactions, and use
strategies related to particular videodisc presentation and
interactive formats and what concepts of scientific methods are
associated with these patterns.

Project group members wi   be trained to conduct the research
and research subjects and settings will be selected. Team
memb- · must learn how to operate the videodisc, implement the
research instruments, tasks, and procedures, and achieve
reliability in their observations. Research subjects from the
middle school grade levels, including both sexes and a range of
ethnic backgrounds, must be identified for both laboratory and
classroom settings.

Based on student reponses to and interactions with the
research videodisc, analyses of research findings will focus on
understanding: 1) promising instructional strategies for creating
an educational videodisc from existing television material using
an authoring system; and 2) effective videodisc presentations and
interactive formats for teaching and learning scientific modes of
inquiry. The results will contribute to knowledge about the

effective application of videodisc technology for teaching a
discovery approach to science.

A comparison of our research findings with those of other
educational videodisc research efforts will help to determine
whether our findings can be generalized to other classrooms, age
levels, subject areas, and applications of videodisc technology.

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Appendix A: Videodisc Technology

     Videodisc is an information storage technology for presenting
video, audio, and text information in a linear and non-linear
format under control of the user.   An optical disc resembles a
phonograph record, and can store up to thirty minutes of motion
video or 54,000 still frames on one side of a disc, each
retrievable extremely rapidly.   Videodiscs are also compact and
pirate-proof.   The videodisc has protective transparent acrylic
coating which protects its pitted surface. and since there is no
abrasion from the laser during playback, it is not subject to
wear.   Unlike videotape, the disc is ideal for freeze-frame, slow
motion, fast forward, and reverse playback.

Competing Videodisc Technologies

     There are two basic types of videodisc technology:
Capacitance and Optical.   Each of these types of videodisc
technology have two formats:

Capacitance formats: 1) the Capacitive Electronic Disc (CED);
                     2) the Video High Density Disc (VHD).

Optical formats: 1) the Optical Transmissive Disc (T/Disc);
                     2) the Optical Reflective Disc (R/Disc).

     The two capacitance formats, CED and VHD, are incompatible.
However, they do have some common features.   A capacitor consists
of two parallel plates: one having a positive charge, and the
other negative.   In capacitance videodisc systems, the disc acts
as one plate of the capacitor, and the stylus as the other.   A
stylus, similar to a phonograph needle, rides over the surface of
the disc and reads information pressed on it.   Picture and sound
information is encoded in microscopic pits on the disc.   The
capacitance of the stylus electrode varies according to the depth
of the pits on the disc.   Pictures and sound information are
interpreted through the capacitance variations between the
surface of the disc and the stylus.

     Although more CED discs and players have been sold than any
other type (over 500,000), they are used almost exclusively to
play back linear programs, such as feature length films to be
viewed in the home.   Each CED disc side holds 108,000 frames
shown at normal television speed (thirty frames per second) for
one hour of linear viewing. Since RCA and all licensees and
marketers have withdrawn this technology from the market, very
few new discs are being pressed, and very limited support for the

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current hardware population exists. The CED players do not accept computer control. Therefore, random access and other interactive features are not available. At this point, there are no CED discs for explicitly educational purposes, and it seems unlikely that this will change in the near future.

Video High Density (VHD) discs also provide 108,000 video frames per side of the disc to be read by the stylus. These discs and their players are marketed in Europe and Japan only, and are not currently available in the U.S. VHD players do accept computer control, and offer a full range of interactivity.

The two optical formats, T/Disc and R/Disc, are also incompatible. However, they too share some features in common. Up to 14 billion microscopic pits can be pressed into a layer of the optical disc, to allow a low-powered laser to detect and deliver a frequency modulated (FM) audio and video signal. Three beams of laser light are focused onto the information layer pressed on the disc. Two outer beams provide tracking guidance, and the center beam reads and carries the video and audio information to be displayed on the video monitor.

The T/Discs and R/Discs can be pressed in two different formats based on differences in the speed at which they revolve: Constant Angular Velocity (CLV) and Constant Linear Velocity (CLV).

At a CAV rate, there are 30 disc revolutions per second (1800 rpm). Each revolution allows the laser beam to read the 525 video picture lines which compose a discrete video image. When displayed at normal television speed of thirty consecutive frames per second, a conventional motion video sequence is constructed. By retracing the same video track thirty times per second, the disc delivers a "still" picture. By varying the numbers of tracks displayed each second, a full range of video image rate can be achieved--from still picture to 100 times normal speed. At normal television speed (30 fps), one disc side holds 54,000 frames or thirty minutes of video programming. All interactive laser videodiscs are pressed in CAV format.

At a CLV rate, the display rate remains constant at 30 frames per second. Since there is more area to cover on the outside edge of a disc opposed to the inside edge, as the reading laser moves from the inner most track to the outside edge, the frame per revolution rate decreases from 1800 to 600 rpm compensating for the change in disc area. The CLV format stores a full hour of video programming, and is used for most feature films and entertainment discs. Access to each frame and variable display speeds are impossible with CLV format, and therefore computer control is eliminated as well.

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Optical Transmissive Disc (T/Disc) allows the laser beam to pass through the information lay'-. By focusing the beam onto a second layer, T/Disc allows a second full "side" of material to be accessed by the user without turning the disc over. This disc format is used in specialized applications only, almost all of which are currently military. There exist very few OTD players and even fewer discs.

Optical Reflective Disc (R/Disc) have a single layer of information on each side, stored in a form of microscopic pits which are coated with a thin layer of lightly reflective aluminium. The reading laser focuses onto this layer and it is reflected back into the system, carrying the information to the video monitor. This is by far the most common form of optical (or laser) videodisc systems, and is usually what is meant by interactive videodisc. At this point, there are estimated to be well over 200,000 systems in a wide variety of training, retail, and learning settings.

Characteristics of the Optical Reflective Videodisc

1) Video Signal. All videodiscs store a video signal designed for playback as an "analog" signal consistent with the North American Standard NTSC (National Standards Television Committee). The picture is a composite video image consisting of 525 interlaced picture lines displayed in a normal television set or monitor. It can also be decoded as an RGB (Red Green Blue) signal to be displayed on a non-television monitor. RGB achieves enhanced video resolution by separating the picture information into the three basic color components and projecting each independently. When mastered from a one inch (c) videotape, the picture quality delivered by the videodisc is well within broadcast standards generally regarded as superior to 3/4" videotape (professional standard) and 1/2" videotape (home standard).

2) Two Audio Tracks. Two fully independent thirty minute audio channels accompanying the video picture. This capacity allows storage of high fidelity stereo sound (estimated as better than 70 db/noise ratio); or two different audio programs for two levels of instruction; or varying interpretations of the same video information.

3) Freeze Frame. By retracing a single video track, the disc can display a single, stable video image. No other video playback offers this capacity. When videotape players display a freeze frame, it is actually only one field on one half of the video picture lines available for each frame. The freeze frame feature using videodisc technology, allows the user to stop the action at

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any time and step forward or back, displaying each picture which would be actually occuring only 1/30 of a second at normal speed. When each image is a still picture in a longer progressive sequence like a film or filmstrip, this allows step-by-step slow motion. When a sequence of different images is pressed onto a disc much like a slide collection, this allows the disc to store the equivalent of 675 slide trays filled with slides.

4) Radial Access. Each single frame has a different number stored as a digital code in the Vertical Blanking Interval (VBI) of the image. This feature allows users to directly access any single frame by its address number regardless of where it is placed on the disc. Since frames are stored as circular tracks, the laser can be rapidly positioned to read the desired track. This means that picture or segment access is much faster and more precise than on videotape, which must wind forward or backward to the location of a frame.

5) Computer Control. By connecting or interfacing a processor to a videodisc player, any interactive capabilities of the computer can be expanded to include videodisc access.

Levels of Interactivity

In 1979, the Nebraska Videodisc Design/ Production Group suggested a classification scheme based on the "levels of intelligence" of various videodisc systems. The classification, which has been widely adopted, is summarized in the following four levels of increasing interactivity.

Level 0: A videodisc or player designed for linear forward playback only. Any videodisc system may function as level 0. Almost all CED and Optical CLV discs are designed for this level.

Level 1: A Level 0 system plus built-in capabilities allowing fast frame accurate access, variable motion, stereo and discrete audio, freeze frame, chapter search, picture stop, and scanning functions. These features are controlled by the user utilizing a simple keypad. The discs themselves may contain embedded codes that allow a running program to stop at a pre-defined place, and wait for an input from the user or to search for a particular "chapter" and begin play. The Level 1 capabilities are inherent in most consumer and VHD players (marketed to homes) including the Pioneer VP-1000, LD-1100, LD-770, 8210, Magnavox 8010, and Sylvania 7200.

Level 2: All of the capabilities of Level 1 plus faster access, increased durability, built-in interface port, and on-board microprocessor with a user-programmable memory. A pre-recorded computer program is stored on one of the disc's

audio tracks in one or more "program dumps." The program is automatically decoded from an audio signal into digital sequences, and loaded into the microprocessor to control access to the information on the disc. Level 2 systems are used for sales, training, demonstrations, and some limited educational applications. These players are largely referred to as "industrial" players, including the Pioneer PR-7820 series, Pioneer LD-V6000, and the Sony LD-1000 series.

Level 3: Either a Level 1 or a Level 2 player interfaced to an external computer. This expands available computer program memory, allowing complex branching and intelligent feedback while minimizing search time. A Level 3 system offers increased potential for interaction between user and system. The computer can generate text or graphics which are overlaid on a video still or motion sequence. The computer can also be programmed to supply computer-based simulations or to record users' input and progress. The disc itself can be relatively simple, containing only video and audio information, needing neither embedded codes nor program dumps. All the necessary "intelligence" is provided by the microcomputer. Systems can be tailored to specific applications using more input and output peripherals such as: touch sensitive display, light pens, color graphic generators, random access audio devices (to provide an external source for sound over still frames), and even special constructions--ranging from a Resusci-Annie manikin used in a videodisc-based cardio- pulmonary resuscitation training program to a tank gunnery rig--designed to better simulate a work environment, and to provide input to the computer from other sources. The Level 3 player is able to discern one video and two audio channels. This permits either stereo sound or the dual use of audio tracks for bilingual and other differentiated sound tracks, for the same visual information.

Level 4: A theoretical domain in which "all things are possible." Level 4 is envisioned as an artificial intelligent operating system, including such future advances as voice activated control. Although there is no accepted definition for Level 4, it is generally used to describe a future level of system interactivity.

New Developments

1) Compressed Audio. There are several new ways to add more audio storage to videodisc systems. Each technique uses what would be video information storage space to store special audio codes. These codes allow an audio message to be delivered to the user while a video image is being displayed. In the space normally allocated to a single video image, up to 20 seconds of "sound over still" may be stored (before, only "sound over motion

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video" was possible). This would allow many hours of filmstrip and audiotape presentations to be pressed onto a videodisc.

2) Compact Disc (CD). Over one million Compact Disc players have sold as consumer audio playback systems. The CD systems use laser/ optical system and a reflective disc to read information stored in digital form. The smaller Compact Audio Discs (4 3/4" in diameter) represent a future direction of technological development--storage of both digital and analog information on the same disc.

3) Compact Disc-ROM (CD-ROM). Utilizing digital storage in a similar format used for Compact Audio Discs, a computer may access an optical/laser disc which store up to 80 megabytes of Read Only Memory (ROM) data. Using digital data for image storage the CD-ROM discs can store several hundred video quality images. CD-ROM disc and its combinations seems to offer important new potential for the future applications of videodisc technology.

Comments

It is not clear which interactive videodisc system will dominate the educational market. Level 3 systems (Optical Reflective Videodisc in CAV rate format) are currently the most relevant for educational applications. Level 3 systems overcome all the problems associated with the limited memory capacity and limited interaction possibilities of the Level 0, 1. and 2 systems. With greater understanding of learner needs and the development of simple standardized interface and appropriate control and access programs, Level 3 systems--which provide responsive and individualized instruction, group use, classroom as well as home use, maximum user control, and intelligent feedback--offer great potential for education. The research videodisc designed by the ETC Videodisc Group is a level 3 Optical Reflective Videodisc.

Appendix A was prepared by Rob Lippincott and Idit
Harel.

Appendix B: The Television Programs and Authoring System

NOVA is a science education series with a viewership of
teenagers and adults.   The one-hour documentary programs explore
the processes of scientific inquiry in a range of subject areas.
The methods and issues of scientific research are explored within
the context of specific themes or topics, taking full advantage
of television as a visual medium.   NOVA is the longest running
science series on television and is the most watched of all
public television programs.

3-2-1 CONTACT is a magazine-format science show produced for
children aged 8-12.   The show segments are designed to excite
youngsters about science and scientific professions.   The series
aims to: introduce different styles of scientific thinking;
stimulate thinking skills critical to the analysis of social
issues related to science and technology; portray science and
technology as a cooperative human endeavor with interesting
career opportunities.   The educational content of 3-2-1 CONTACT
emphasizes key concepts and principles rather than scientific
facts.

Both NOVA and 3-2-1 CONTACT are extensively used by teachers
in the classroom.   According to the recently released Corporation
for Public Broadcasting School Utilization Study (Riccobono,
1985), a survey of instructional television during 1982-1983
revealed that both NOVA and 3-2-1 CONTACT are among the
twenty-five most widely used inst ictional series in schools.
More students watch NOVA than any other instructional television
series, regardless of subject area or grade level. A total of
10,517,000 students viewed NOVA and 551,000 students viewed 3-2-1
CONTACT during the 1982-1983 season.   In addition, 3-2-1 CONTACT
is viewed in informal educational settings, such as science
museums, scout clubs, and 3-2-1 CONTACT science clubs.

The videodisc software is created by an authoring system,
called Authority (TM), that produces interactive videodisc
courseware without custom programming.   Authority is an
English-based, menu-driven authoring system for developing
videodisc courses for industrial training and electronic
merchandising.   The system permits designers to select from a
number of built-in learning formats and insert the course
material.   The videodiscs produced with this level 3 system must
be played on hardware configured by ITS: a videodisc player, an
IBM Personal Computer; a high-resolution color RGB monitor with a
touch screen; and a specially designed interface called the
ITS-3100 Controller that links the videodisc player to the
computer.

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