Using Videodiscs in Instruction: Realizing Their Potential Through Instructional Design

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The authors examine the state of the art in instructional theory and its potential use and application to the development of intelligent videodisc systems. Several recommendations are presented including the need to use instructional design theory and design specialists in videodisc training programs.

There is in the literature a sense of excitement and urgency about the use of videodiscs in education. Bork, Luehrmann and Schneider (1977, 3) capture this mood when they write, in a summary of conference proceedings on intelligent videodisc systems:

> An important moment is occurring, the moment when the computer plus powerful associated audiovisual capabilities can have a major effect on education at all levels. . . . [I]t is realized that hardware alone is not sufficient but that hardware sales will be driven by the availability of well-tested, effective course materials.

This same theme is reflected in this discussion, as an attempt is made to show how the systematic application of knowledge about instruction is essential if the full potential of videodisc technology is to be realized. Specifically, we will begin by discussing the *need* for intelligent videodisc systems in our educational system. The first section, a brief review of the state of the art in intelligent videodisc systems, describes the capabilities and limitations of these systems. This is followed by a similar review of the state-of-the-art aspects of instructional theory that have implications for the design of hardware, software, and courseware for intelligent videodisc systems. We also look at some of the problems inhibiting introduction of videodisc systems into education, with primary focus on the lack of sufficient high-quality courseware. Finally, a section on new horizons will discuss solutions to these inhibiting factors, including general recommendations, recommendations for making better use of present knowledge, recommendations for the design of hardware and software for intelligent videodisc systems, and recommendations for the development of instructional models and theories to meet the needs of courseware design for videodisc systems.

One final clarification is in order. As our emphasis is on "intelligent" videodisc systems—that is, videodisc players and monitors interfaced with an external microprocessor or minicomputer—the literature on computer-assisted instruction (CAI) is directly relevant, and indeed it informs much of the

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discussion. Consequently, references to minicomputers or CAI which do not explicitly mention videodiscs should nonetheless be understood to apply directly to intelligent videodisc instructional systems also.

Intelligent Videodisc Systems: State-of-the-Art

As with any powerful tool, it is important to understand the capabilities and limitations of the intelligent videodisc system in order to be able to take full advantage of its potential for education. What follows is a brief description of its most important capabilities and limitations. (*Editor's Note*: See issues 1:4 and 2:2 for other descriptions of videodisc systems.)

Capabilities

Experts in videodisc technology consider intelligent videodisc systems to be the biggest breakthrough in instructional technology since the Gutenberg press. The enthusiasm is owing to the new technology's multiplicity of capabilities, in terms of media, storage, learner motivation, cost advantages, advantages for learner productivity, and likely second-generation capabilities.

Media Capabilities. The fact that intelligent videodiscs can incorporate all existing instructional media (namely, print, audiovisual displays, and computer-assisted instruction) in a single medium is certainly one of its most impressive features. Moreover, this integration retains virtually all of the advantages of each of the component media in a form which previously required cumbersome and expensive multimedia systems.

Textual material, transparencies, 35mm slides, filmstrips, microfilm, motion pictures, and videotape—all these visual media can be accommodated on a videodisc. According to Schneider (1976), conventional slide/tape shows, postcard reproduction series used by fine arts students, and microscope slide series used by students in the life sciences could all be replaced by videodiscs. By adding still-frame sequences to existing motion pictures, literally millions of dollars worth of existing educational films, videotapes, etc., could be rejuvenated as well.

Videodiscs provide two audio tracks which can be used to produce stereophonic sound or can be used independently, for example to record in two different languages for foreign-language instruction or to record at different levels of sophistication for different groups of learners. And now audio options include still-frame, slow-motion, or reverse modes, or continuous audio with still frames. A recent development is the provision of more than two audio tracks.

The ability of videodiscs to produce both motion and still-frame sequences has, in Bennion's words, "produced a new dimension for audio-visual media" (Heuston 1977, 92). Combined with the ability to vary direction (forward or reverse) and speed (normal, slow, fast) and with such features as automatic and chapter stops, the still/motion capability provides powerful instructional possibilities. Automatic stops will automatically switch the display from a motion sequence to a still-frame sequence in which supplementary graphic and textual material can provide in-depth treatment of the preceding motion display (rather than the inescapably superficial treatment produced in conventional motion picture displays).

Random access, made possible by electronic addressing of each videodisc frame, in combination with the memory and processing capabilities of a computer (whether an internal or external microprocessor, or an external central processor), provides the further capability of interactive, individualized instruction. Specific capabilities resulting from intelligent systems include:

1. branching, with either fixed or dynamic choices (hence, immediate feedback on practice)
2. item generation
3. testing
4. constructed response and answer analysis (matching student responses to correct or incorrect feedback alternatives)
5. scoring
6. record-keeping (including, for example, the length of time or the number of trials taken to complete a segment)
7. student status feedback
8. simulations and games
9. computer graphics (which can be overlaid on videodisc output on a single screen or can be output on a separate screen for higher resolution).

The opportunities for day-to-day collection and analysis of student performance data implied in the foregoing list are cited by Hirschbuhl (1977) as one of many reasons for support of computer-based instruction. *Storage Capabilities*. The numbers here are particularly impressive. A single thirty-minute videodisc contains 54,000 tracks or frames per side, which are read at the rate of 30 per second or 1,800 per minute. Still frames are produced by reading the same frame repeatedly. When data is in binary form (machine readable), each of the 54,000 tracks provides 185,625 bits of memory, for a total of 1.25 billion bytes per disc side. In addition, system cost, disc cost, and error rate are approximately twice as good as for a minifloppy disc (Braun 1977). Also, at a compression factor of 300, a single disc can store up to 150 hours of audio. These capabilities will be multiplied many times when digitizing of textual material will make possible storage of 100,000 characters per frame, rather than the current 500 characters (1 disc = 108,000 frames = 13 gigabytes = 13,000,000,000 bytes of information).

Motivational Capabilities. By integrating motion pictures with traditional instructional formats, videodiscs enhance the motivational capability and visual appeal of instruction.

Costs. In general, while the material and hardware of videodisc systems are relatively inexpensive, authoring and mastering videodisc instruction and operating and maintaining an on-line intelligent videodisc system have high fixed costs. The key to making videodisc instruction cost-effective is selling a sufficient number of copies and/or ensuring sufficient use of each individual videodisc to spread out those high fixed costs (Heuston 1977).

More specifically, cost considerations may be broken down into costs for materials, for hardware, for development, for production (i.e., mastering and replication), and for systems operations and maintenance. Bennion and Schneider (1975) provide a model for estimating the development and production costs of interactive videodisc instruction per student hour which, in effect, amortizes the high fixed development and production costs over the number of copies of the videodisc produced (that is, over the market size), the number of times each of these discs is used, and the length of instruction available on the disc (that is, the percent of the disc devoted to still frames). Bennion demonstrates that "when more than about 15 to 20 percent of the disc is devoted to still frames, the cost of instruction per hour is essentially constant" (Heuston 1977, 83). Hence there is no significant cost reduction to be gained by an all-still-frame disc, and media selection should be based on the need for motion vs. still-frame sequences as well as the desired length of the instruction.

Equally if not more important is the fact that, when the number of videodiscs produced is one thousand or more and/or when the number of uses increases substantially above five uses per videodisc, then the cost per student hour is *very* low (Heuston 1977, 91). When dealing with the same program, for example, 100 discs each used 100 times, or 10,000 discs each used once, results in an hourly cost per student of about $0.75; whereas 1,000 discs each used 100 times, or 100,000 discs each used once, produces an hourly cost of less than $0.10!

In addition to the cost advantages realizable when videodiscs enjoy widespread distribution and utilization, Hirschbuhl (1977) cites (1) lowered attrition rates, (2) improved student performance, (3) savings in student and teacher time, and (4) savings in the student-teacher ratio, as benefits accruing from computer-based instruction.

Learner Productivity. Due to the capabilities for interactive, individualized instruction on videodisc systems, learner productivity with such systems may surpass that normally obtained with books or motion pictures.

Second-Generation Capabilities. It is very useful to consider capabilities in terms of the various videodisc systems soon to be available. The state-of-the-art technology in use today is the *intelligent* system, which fully interfaces a videodisc player with an external microprocessor, allowing truly interactive instruction. Added to display of all print and audiovisual media, two audio tracks, control of random access and display modes, and branching are answer analysis, item generation, scoring, and record keeping. The microprocessor also allows the production of simple computer graphics.

For *second-generation intelligent systems*, hardware research and development efforts focus on: (1) providing continuous audio with still frames and providing multiple audio tracks; (2) improving storage of digital information on disc—allowing computer programs, for example, to be stored directly on the videodisc for dumping into a microprocessor (which would then execute the desired instructional sequence); and (3) outputting both videodisc and computer-generated graphics on the same screen.

Some of these capabilities exist already. For example, Westinghouse Technical Training Operations in Baltimore, Maryland, has already engineered a system which stores digital information and provides continuous audio with still frames, as well as multiple audio tracks. In addition, capabilities available by interfacing one or more of the myriad of peripherals being produced by a burgeoning cottage industry include activation of the system by speech recognition and response by voice synthesis, inputting of visual stimuli, and hard-copy printouts. The possibilities here would appear to be limited only by one's imagination!

Bennion (1974) and Hirschbuhl (1977) both describe a still higher level of sophistication (beyond the intelligent system) in which the videodisc system is connected online to a central processing unit, thereby greatly enhancing the memory and processing capabilities of the system, although system costs would increase and portability would decrease because the system would no longer be stand-alone. To offset these higher communication costs, Hirschbuhl (1977, 86) recommends a technique called "distributive processing," in which multiple minicomputers, each capable of supporting many terminals, are connected to a large host computer. Finally, Bennion (1974, 3) describes the addition of a magnetic read-write head and of an oxide strip to the center, unused portion of the disc "so that a record could be made of the strategy used and answers given." The oxide strip would later be read and erased for future use, while the results would be analyzed and printed out for both student and teacher to review.

In short, intelligent videodisc systems combine the visual appeal of motion pictures with the capabilities for interactive, individualized instruction of traditional computer-assisted instruction systems and the heightened learner productivity that such systems produce. While future prospects look even brighter, videodisc systems already afford significant cost advantages over other media, especially when used by large numbers of learners.

Limitations

Two comments surface repeatedly in the literature concerning limitations of videodisc systems. First, optical videodiscs are a read-only memory medium, meaning that once the disc is pressed, it can no longer be modified directly. This indicates the need for an intermediate authoring system (such as an interactive videotape system) for designing, evaluating, and revising instruction before it is produced on disc in final form. Second, videodisc mastering is an expensive process requiring high-volume sales to make it truly cost-effective.

Instructional Science: State-of-the-Art

A consistent theme of much of the literature about videodisc applications for instruction has been the need for well-designed course materials. In order for a tool to work effectively, it must be used by one who has a good understanding of methods (or techniques, or procedures) for using that tool. In a similar way, we believe strongly that the only way to realize the tremendous potential of videodiscs as an instructional tool is through a thorough understanding of (1) methods of instruction (of their effects for all kinds of students and all kinds of subject matter) and (2) the bases for prescribing their optimal use. Such knowledge about methods of instruction is the concern of the field called Instructional Science (see, *e.g.*, Gallagher 1979; Reif 1978; Reigeluth, Bunderson, and Merrill, 1978), and this knowledge has been accumulated in the form of principles, models, and theories of instruction.

In its infancy, instructional science focused mainly on very general and vague method variables, such as discovery vs. expository, lecture vs. discussion, and inductive vs. deductive methods. The results of such investigations were highly inconsistent, primarily because there was often more variation within each method than between methods—*e.g.*, two discovery methods were likely to differ more than a discovery and an expository method differed.

As a result, instructional scientists soon began to analyze methods of instruction into more elementary components and to investigate the effects of each such "strategy component" under fairly controlled conditions. From these efforts has been generated a considerable body of piecemeal knowledge—isolated principles of instruction—and these principles have been empirically validated and found to be highly reliable (*see* Fleming and Levie 1977, for an excellent summary of many such principles). This focus in instructional science (on investigating very precise, elementary, strategy components) has been an important phase in the development of the field, but the resulting knowledge has been too piecemeal to be very useful to most instructional developers.

Consequently, some instructional scientists now recognize the need to integrate existing knowledge (and to extend that knowledge where important gaps are found) into models of instruction which are optimal for different sets of conditions and desired outcomes (see *e.g.*, Gropper in press, and Reigeluth 1980a).

There are at least two major types of design considerations: (1) *micro* considerations, which apply to teaching a *single* idea (such as the use of examples and practice); and (2) *macro* considerations, which apply to the teaching of *many* related ideas (such as sequencing and systematic review). About seven years ago, M. D. Merrill and his associates began to integrate much of the existing knowledge about micro design considerations (for single ideas) into a number of models of instruction. Those models, along with prescriptions for their optimal use, are referred to as the *Component Display Theory*.

Five years ago, C. M. Reigeluth and M. D. Merrill began to integrate much of the existing knowledge about macro design considerations (for many related ideas) into three models of instruction. Those models, along with prescriptions for their optimal use, are referred to as the *Elaboration Theory of Instruction*. These three sets of models are primarily concerned with strategies to optimize the effectiveness and efficiency of instruction (although the Elaboration Theory devotes a moderate amount of attention to motivational considerations).

Finally, about three years ago, J. M. Keller and his associates began to integrate much of the existing knowledge about the *motivational design of instruction* on both the micro and macro levels. These models are still in preliminary stages of development but show great promise for the discipline. These three sets of instructional models are briefly described below.

The Component Display Theory

Merrill's Component Display Theory (Merrill, in press; Merrill, Reigeluth, and Faust, 1979; Merrill, Richards, Schmidt, and Wood, 1977) is intended for cognitive objectives. It is a prescriptive theory that is comprised of (1) six major models of instruction, each of which can be used in varying degrees of richness, and (2) a unique *system for prescribing those models* on the basis of the kind of objective chosen for an idea. The degree of richness of the model is then prescribed on the basis of the difficulty of the objective in relation to the ability level of the students.

Each of the six models of instruction integrates knowledge about how to optimize instruction for one of six kinds of objectives for any given idea; and each kind of objective corresponds to a different level of cognitive processing for a given idea. The most fundamental difference occurs between objectives requiring *recall, application*, and *discovery*. Another difference exists between recall objectives that require *verbatim* recall and *paraphrased* recall. The third and final difference lies between objectives that require recall of specific *instances* (or cases) and those requiring recall of *generalities* (which apply to more than one case and make no reference to any specific case).

To summarize, the six kinds of objectives are to remember an instance verbatim, an instance paraphrased, a generality verbatim, a generality paraphrased, an application of a generality to "new" instances, and a discovery of a "new" generality. Each of these six kinds of objectives requires a different instructional model to optimize learning at that level of cognitive processing.

For the most common kind of objective—applying a generality to "new" instances—this theory calls for presenting three major strategy components: (1) a *generality*, such as the statement of a principle or the definition of a concept; (2) *instances* showing the application of that generality to specific cases, such as demonstrations of the principle or examples of the concept; and (3) *practice* in applying that generality to new instances, such as solving a new problem or classifying a new example of the concept. The practice should always be followed by feedback about whether the student's answer was right or wrong, and why. The examples and practice items should be different from each other in as many ways as the student is likely to encounter in the real world, and they should be arranged in a progression of difficulty from easy to difficult (which may include variation in response mode as well as manipulation of variable attributes). Moreover, in order to facilitate learner control, the generality, examples, and practice with feedback should all be clearly separated and labeled rather than run together in a continuous prose passage.

Learner control (Merrill 1980) is the Component Display Theory's way of dealing with individual differences among students. It requires some brief student training in two ways: (1) the nature of each strategy component, and (2) the way in which each component helps the student to learn (*i.e.*, to overcome a different kind of learning problem). With such knowledge, the student is well equipped to pick and choose from the "menu" of strategy components (primarily the generality, the instances, and the practice items) to make his or her own optimal instructional design, while skipping over strategy components that are not necessary. Rather than designing "visual" instruction for some students and "verbal" instruction for others, for example, both representations should be made available to all students. (It is also likely that the vast majority of students are not strictly verbal or strictly visual and can therefore benefit from having both available by enabling dual encoding to occur.)

In order to increase the richness of this model, the number of instances and practice items could be increased. In addition, each of the three major strategy components (generality, instances, and practice) could be enriched with such secondary strategy components as an alternative representation (*e.g.*, a diagram, picture, or flow chart), and an *attention-focusing device* (*e.g.*, underlining, exploded diagrams, or common errors). The richest version of this model would include a large number of instances and practice items, as well as both of the secondary strategy components described above (plus some that have not been mentioned here). For an idea or objective that is easy in relation to student ability, however, the generality alone might suffice.

This one instructional model alone from the Component Display Theory incorporates work by Bruner (alternative representations, especially enactive, iconic, and symbolic), Glaser and Homme (rule—or rule-example—as generalities and instances), Rothkopf (mathemagenic information, primarily under the rubric of attention-focusing devices), Skinner (shaping in the form of progression of difficulty and overt responses in the form of practice), Kulhavy (feedback for practice), Gropper (response modes and stimulus characteristics), Horn (information mapping for separating and labeling strategy components), Markle, Merrill, and Klausmeier (strategies for teaching concepts, especially instance divergence—instances and practice items as different as possible from each other—and "matched" or "close-in" nonexamples—instances which demonstrate common errors, specifically overgeneralization in the case of concept learning), to mention just a few of the most prominent people whose work is integrated into this one model.

The influence of the prose learning people (especially Rothkopf and Frase), the learning taxonomy people (especially Gagne and Bloom), and the structure of memory people (especially Kintsch and Norman) are also readily apparent in the derivation of the five kinds of objectives based on different levels of cognitive processing (including both storage and retrieval). Although the Component Display Theory integrates much existing knowledge, it is comprised of a considerable amount of new knowledge which was developed by Merrill as he encountered gaps in the existing knowledge, and which was needed to form such an integrative and complete set of models for different kinds of cognitive objectives. The two-dimensional classification of objectives according to both content type and behavior level is one such innovation.

It is very difficult to do justice in such short space to an instructional theory that synthesizes so much knowledge about learning and instruction. The individual strategy components in each model have undergone considerable empirical testing in controlled settings. This body of research has shown significant differences for all of the above-mentioned strategy components (see Merrill, Olsen, and Coldeway, 1976). No research has been done, however, to test each whole model to determine the relative importance and the interactive and duplicative effects of each of the strategy components comprising each of these six models.

The Elaboration Theory of Instruction

The Reigeluth-Merrill Elaboration Theory of Instruction (Reigeluth, 1979a; Reigeluth, Merrill, Wilson, and Spiller, 1980; Reigeluth and Rodgers, 1980; Reigeluth and Stein, in press) is also intended for cognitive objectives. It is a prescriptive theory that was developed to integrate existing knowledge about *macro* design considerations (for many related ideas), but it considerably extends that knowledge where deficiencies were found. It is a major attempt to use both an analysis of the structure of knowledge and an understanding of cognitive processes and learning theories to develop strategies for selecting, sequencing, synthesizing, and summarizing the ideas in a course. It states that, if cognitive instruction is designed according to the appropriate model, then that instruction will result in improved levels of achievement, synthesis, retention, transfer, and motivation.

Most instructional design experts have been using a hierarchical task analysis procedure based on Gagne's cumulative learning theory. But the hierarchical, learning prerequisite relationship is only one of four major kinds of relationships in cognitive subject matter (*i.e.*, only one of four major kinds of knowledge structures). And the process of "cumulative learning" is only one of several major kinds of cognitive learning processes. Another major kind of cognitive learning process is schema theory and its well-known cousin, subsumption theory.

The elaboration theory integrates both of these major kinds of cognitive learning processes and all four major kinds of knowledge structures into three models of instruction. It also has a system for prescribing those models on the basis of the goals for the whole course of instruction. Goals are classified according to one of three types, and each type requires the formation of a different type of cognitive structure to optimize achievement of that type of goal. In all three models a general-to-detailed sequence is used to optimize the formation of stable cognitive structures. However, the way the general-to-detailed sequence is operationalized varies considerably from one type of cognitive structure to another.

In all three models, the instruction begins with a special kind of overview which is derived on the basis of a *single* kind of knowledge structure and *epitomizes* that knowledge structure rather than summarizing the course content. In this context, *epitomizing* means providing concrete examples and practice items, as well as generalities, for a few fundamental and highly representative ideas, whereas *summarizing* means providing only abstract generalities for all major ideas. Then the instruction proceeds to add detail or complexity in layers across the entire breadth of the course content, one layer at a time, until the desired level of detail or complexity is reached. Learning prerequisites are introduced only as they become necessary within each layer.

Each model is adjusted in certain ways to make it appropriate for the ability level and experience of the students and the complexity or difficulty of the content. For instance, the amount of material between review-and-synthesis components is adjusted to produce an optimal learning load, which varies according to the difficulty level of the content in relation to the ability level and experience of the students. Considerable detail has been worked out on the nature of each model, and even on the procedures for designing instruction according to each model.

Motivational Design of Instruction

In addition to these two instructional theories, valuable work has been done recently on the motivational design of instruction (i.e., on prescriptions for the improvement of the motivating characteristics of instruction). John Keller's (1979) efforts to develop a descriptive theory of motivation as it relates to instruction and performance are highly integrative and innovative. This work synthesizes knowledge about motivation from the full range of theoretical traditions, i.e., from pure behavioral to pure humanistic.

On the most general level, Keller's theory postulates that motivation is a function of person and environment variables. Therefore, it draws on *environmental theories* comprised of conditioning principles and physiologically based drives; on *humanistic theories* that postulate a fundamentally free will as the basis of motivation; and on *social learning theories* that look at the interactions between a person and the environment. Within the domain of social learning theory, Keller draws heavily from expectancy-value theory, which assumes that motivation is a multiplicative function of expectancies and values. Keller has also incorporated aspects of attitude theory, decision theory, attribution theory, cognitive evaluation theory, equity theory, cognitive dissonance theory, locus of control, and learned helplessness (see Keller 1979, 28-30, for references for all of the above theories).

This integrative and innovative work on a descriptive theory of motivation as it relates to instruction has important implications for instructional scientists, but Keller has taken it one step further by developing prescriptions for the motivational design of instruction (Keller, in press). The prescriptions include method variables for arousing and sustaining attention, for connecting instruction to important needs, for building confidence in success, and for reinforcing behavior. Although much work remains to be done, Keller's efforts are another example of an attempt to develop integrative instructional models in instructional science.

Section Summary

In this section we have described some recent developments in instructional science that have important implications for the design of courseware, software, and hardware for intelligent videodisc systems. The *Component Display Theory* integrates much knowledge about ways to design highly effective and efficient instruction on the micro level—the level of an individual idea. It includes a number of different models, the most important of which prescribes the use of a generality, examples, and practice, as well as secondary strategy components and learner control, for teaching a single idea at the application level.

The *Elaboration Theory of Instruction* integrates much knowledge about ways to design highly effective and efficient instruction on the macro level—the level of many related ideas. It includes three different models, all of which utilize: (1) a general-to-detailed sequence for designing the main structure of a course, (2) learning prerequisite sequences nested within parts of that main structure, and (3) additional strategy components that provide for explicit synthesis of the ideas and for systematic review.

Finally, some highly integrative model-building for the *motivational design of instruction* was described. This work applies to both the micro and macro levels of instruction. It is likely that other integrative efforts have been made in these areas, and undoubtedly similar integrative efforts have been initiated in such other areas of instructional science as media selection, simulation and games, management strategies, and tutorial dialogues.

It has been argued above that instructional science can provide much of the knowledge necessary to design the high-quality interactive courseware that is essential for videodiscs to achieve their potential in education. However, the demands of intelligent videodisc systems on instructional science are unlike the demands that have heretofore been made on this fledgling discipline. The implications of these new demands will be discussed later in this paper. Prior to that discussion, however, it is important to examine some of the other factors presently inhibiting the introduction of videodisc systems into education.

Factors Inhibiting Introduction of Videodisc Systems into Education

When Braun (1977) contrasts the three hundred years that it took for books to become an integral part of society with the few decades within which television (fifty years) and computers (thirty years) have achieved comparable status, he depicts graphically how "one of the major problems with introduction of these technologies (microcomputers and videodiscs) has been the rates of development of technologies in these areas." More specifically, Braun cites inadequate system reliability, inadequate teacher preparation, high costs, inconvenience (that is, size), confusion over language (that is, should ALGOL, APL, BASIC, LOGO, PILOT, or Pascal be used and when), and lack of sufficient high-quality courseware as factors inhibiting more widespread adoption of microcomputers and videodiscs in education.

Marketing costs, poor management by federal funding agencies, authoring costs, and efforts by individuals rather than teams are all outlined by Braun as particular aspects of the courseware problem. Two other aspects of this problem are (1) lack of application of current knowledge about instructional design, and (2) the need for the further development of integrative and comprehensive instructional models.

A related problem identified by Hirschbuhl (1977), which he calls "peopleware," is the shortage of professionals qualified to produce such courseware, coupled with the expectations by institutional policy makers that faculty can do such courseware development on their own time! According to Hirschbuhl, constantly changing software, insufficient courseware, lack of evaluation data to assist policy makers in determining for which subject areas and which populations computer-based instruction would be most or least appropriate, as well as a lack of "peopleware," are current disadvantages of computer-based or videodisc instruction.

He contrasts these with what he calls "inherent" disadvantages, namely, the costs of operating and maintaining on-line systems. Unlike such inherent difficulties, current problems can all be solved.

New Horizons: Solutions to Inhibiting Factors

Braun (1977) describes ways in which microcomputers have significantly alleviated problems associated with system reliability, teacher preparation, cost, and size. Further, he advocates the formation of a consumers' union for educators which would protect consumers against the competing claims of the various videodisc manufacturers. He recommends a careful study of the language needs of computer-based courseware. This would serve, among other things, to identify the educational applications for which each of the several available languages is best suited, and it would suggest ways to maximize the transferability of courseware from one system to another.

This leaves the courseware problem as the most important to be overcome to enable intelligent videodisc systems to realize their tremendous potential for improving education. Three sets of recommendations related to the courseware problem are presented below.

Make Better Use of our Present Knowledge

Braun (1977) recommends a two-stage approach to courseware development in which support should be provided for courseware development teams to produce from scratch, while at the same time supporting the identification, evaluation, and improvement of already existing educational materials. With respect to production from scratch, it is recommended that funding agencies provide the resources for developing the first stock of educational videodiscs and that they provide those resources only to development teams that include instructional design experts as well as subject matter experts and media production experts. Without such funding, it is unlikely that the private sector will risk the relatively large amount of investment necessary, considering that the size of the market is unknown and the techniques of educational disc development are unproven. Without good educational discs, the market will remain small, and without a large market, the private sector will not invest the resources necessary to make good educational discs. Once the market develops, such external funding should be unnecessary.

One additional precaution is in order with respect to production from scratch: very few instructional design experts are familiar with many of the latest (and most important) developments in instructional science. This is especially true among specialists in the field. It is recommended that any such development project be preceded by a training seminar for the design specialists, to be conducted by those instructional scientists who are at the forefront of developing integrative and comprehensive models of instruction.

In addition to producing materials from scratch, it is possible to make considerable use of existing knowledge (as well as to save substantially on development costs) through the identification, evaluation, and improvement of existing educational materials. Heuston (1977) recommends concentrating first on upgrading existing motion pictures by incorporating into them sequences of still frames, and he points also to the lessons to be learned from the TICCIT (Time-shared Interactive Computer-Controlled Information Television) System, developed jointly by the MITRE Corporation and Brigham Young University. The TICCIT System is noteworthy for, among other things, its careful application of instructional science to the design of courseware materials (Merrill, Schneider, and Fletcher, 1980; Reigeluth 1979b). Such materials represent a valuable base that could be revised and enlarged to take advantage of the capabilities of the intelligent videodisc.

One additional recommendation is that both the evaluation and revision of existing educational materials be based on instructional science. Standard instructional evaluation procedures are well-suited for empirically identifying weaknesses in educational materials, but they are grossly inadequate for prescribing revisions. Presently, revisions are usually prescribed on the basis of intuition—if at all. This is haphazard and inadequate. Furthermore, a thorough knowledge of principles of instruction permits a thorough analytical (or intrinsic) evaluation, as opposed to an empirical (or extrinsic) evaluation, of existing materials. An analytical evaluation is considerably quicker, less expensive, and, if done by a top professional, more effective in diagnosing specific weaknesses in the materials. In essence, it is recommended that the evaluation and revision team include instructional designers—but again, under the requirement that they partake in a training seminar prior to the project.

Further Development of Instructional Science

Although present knowledge about instructional design is sufficient to allow significant improvements in the quality of educational materials, that knowledge is far from complete. Instructional science is far from realizing its potential for improving the quality of courseware. Inasmuch as videodiscs now offer for the first time the capability of efficiently integrating print, audiovisual displays, and interactive computer-based instruction within a single learning sequence, models of instruction that prescribe how to intersperse and integrate such delivery modes are now necessary. The most significant implication of videodiscs for the further development of instructional science is the need for instructional scientists to integrate the multitude of existing strategies and narrow models of instruction from diverse areas into more comprehensive models.

Instructional strategies may be understood to include strategies for organizing, delivering, and managing instruction. All three classes of strategies are applicable to learning outcomes in any of the cognitive, affective, and psychomotor domains. The synthesis or integration of instructional strategies implied by videodisc technology needs to proceed at two levels—within and among these three classes of strategies.

Synthesis Within a Strategy Type. As was indicated above, Merrill's Component Display Theory and the Reigeluth-Merrill Elaboration Theory serve as examples of synthesis within a strategy type, namely, organizational; and, in fact, these two theories are themselves being combined to provide a single basic organizational theory. Similar efforts are being, and must continue to be, made within the other strategy types. Keller, for example, has been developing integrated models for the motivational design of instruction. Other areas needing similar attention include media selection, management of instruction (*e.g.*, learner control), simulation and games, and "intelligent" tutorial dialogue.

Within each of these strategy types, it seems likely that the most useful approach will be to develop a few basic models that will have fairly broad applicability (although restricted to one major type of strategy—*e.g.*, delivery). Then, for any given application of a basic model (in developing instruction for a videodisc), that model would be adjusted—primarily by adding appropriate strategy components—on the basis of specific factors that called for modifications in order to optimize the desired outcomes under the specific educational conditions. Naturally, the prescriptions for when and how to make such adjustments would accompany each model.

Synthesis among Strategy Types. In addition to synthesis within each type of strategy, attention must also be focused on synthesis among all strategy types. It seems likely that this will best be done by developing "meta-models," one (or a few) for each major type of goal (*e.g.*, intellectual development, attitude development, social development, motor development). Each meta-model would prescribe ways in which the various basic "area models" (i.e., models within a single strategy type or "area") should be combined for optimizing the desired outcomes. For example, a certain game model might be prescribed first. After introducing the game, an organizational model might be prescribed to teach some of the skills needed to overcome a new obstacle encountered in the game, and so on. Such meta-models would have to make provision for diverse goals (within the major goal type to which it applies) and diverse conditions (such as types of students, content, and constraints). For instance, there might be different meta-models for teaching students how to apply principles vs. teaching them how to discover principles; and a single meta-model for teaching them how to discover principles may provide different prescriptions for eight-year-olds vs. for twenty-year olds, or for physics principles vs. principles related to the critical analysis of literature, or for situations where discussion groups will be an important part of the instruction vs. situations where the instruction must be stand-alone.

One thing is certain: that to meet the need to develop high-quality courseware for videodiscs, instructional science must provide more comprehensive and integrated models of instruction. Hence, our major recommendation is that instructional scientists devote more time to such activities and that funding agencies devote more resources to such activities.

Intelligent Videodisc System Design

Current developments in instructional science indicate several important characteristics that should be incorporated into the design of hardware and software for intelligent videodisc systems in order to best implement high-quality courseware. On the basis of the instructional models and theories summarized earlier, Figure 1 shows a hypothetical sequence that a learner might follow on a videodisc system. The following is a brief but fairly technical explanation of each step in that sequence. Readers who are new to these ideas may wish to skip to "Hardware and Software Recommendations," below.

1. Log on.
2. Select a course from the course menu.
3. Review an among-set expanded epitome of sets already completed.
4. Select a lesson from the lesson menu.
5. Review a within-set expaned epitome of lessons already completed.
6. Complete the lesson:
   6.1 Complete the lesson introduction.
   6.2 Complete each of the lesson topics.
   6.3 Complete the lesson summarizer and synthesizer.
   6.4 Complete the lesson test.
7. Complete the new within-set expanded epitome.
8. Complete the synthesis text (whenever a whole set is completed).
9. Complete the new among-set expanded epitome (whenever a whole set is completed).
10. Complete the among-set synthesis test (only after step 9).
11. Go to step 4 or log off.

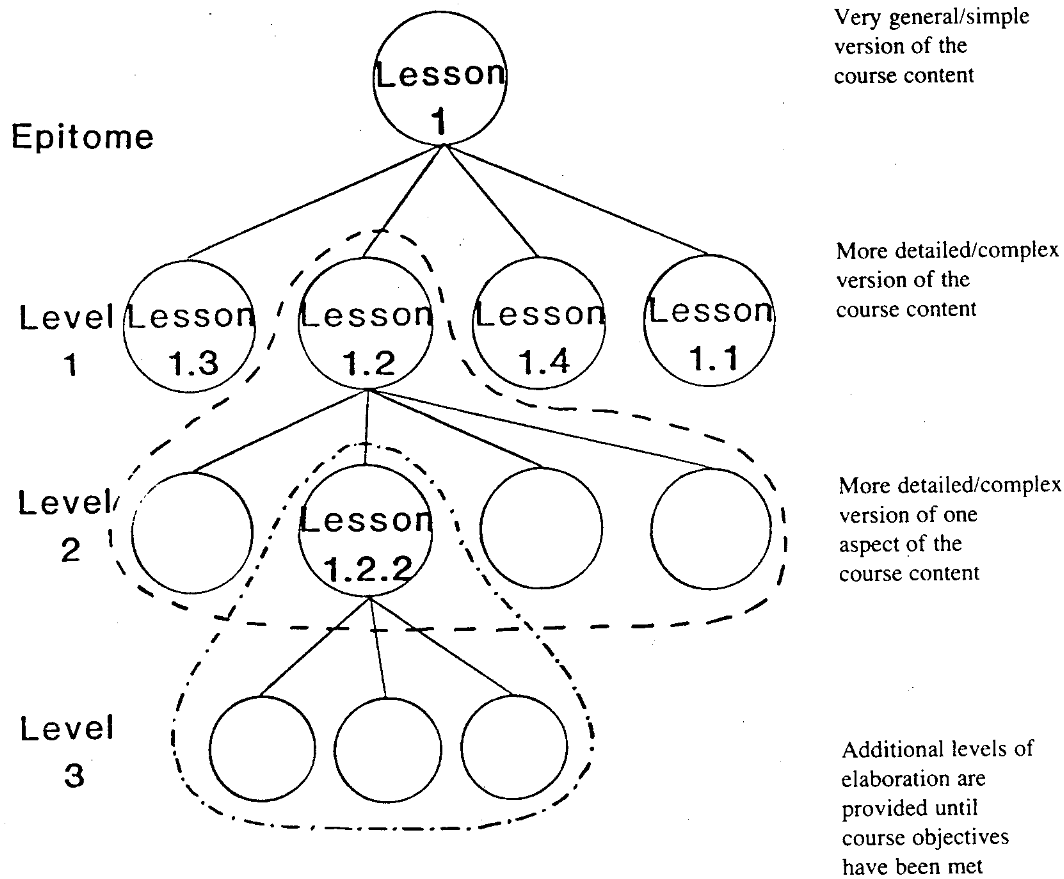
Figure 1. A Hypothetical Sequence That a Learner Might Follow on a Videodisc System.

1. *Log on.* Logging on with a name or identification number would automatically access records of that learner's abilities, cognitive styles, and previous work, which would be used by the system to individualize the instruction. In the case of a home system, that information would be stored on the system's "boot diskette." In the case of a school system, it would be stored in a connected minicomputer. Information about the learner's abilities and cognitive styles would be incorporated mainly in the "advisor" recommendations (described below), whereas information about his or her previous work would be reflected in the menus (described below).

2. *Selecting a course.* The course menu would be shown automatically as soon as a learner logged on. It would probably be taxonomic, with a number of levels. For example, the top level, which would be displayed first, might have such entries as science, sociology, history, psychology, or literature. After selecting one (*e.g.*, "science"), a breakdown of science courses would automatically be displayed, such as physics, chemistry, biology, astronomy, earth science, etc. For a home system, the course menu might also be on hard copy, and the learner would go to the public library or school library to pick out the disc that corresponded to the desired course. For a school system, this menu would be stored in the connected minicomputer, but the learner would still have to then go and pick out the appropriate videodisc. Courses already completed by the student would be so indicated on the menu.

3. *Review an among-set expanded epitome of sets already completed.* After the learner has decided on a course and secured the appropriate videodisc, that disc would then automatically present a special review of the major units of content which that learner has already mastered. Lessons would be designed such that each is an elaboration on a more general or more simple version of fundamentally the same content (see the description of elaboration theory above). A "set of lessons" is defined as any one lesson plus all of the lessons that comprise the first level of elaboration on it (see Figure 2). Each time a learner enters a course, the system will automatically present a special review (or expanded epitome) of each set that the learner has completed (*i.e.*, each set for which all lessons in that set have been completed). While the major purpose of this review is to help the learner to decide which new lesson would most interest him or her, it also provides periodic review of previously learned content and reminds the learner of the meaningful context of the to-be-learned content.

4. *Select a lesson from the lesson menu.* After the learner has completed the among-set review, the menu is automatically displayed, again taxonomically. First, eligible sets are listed by level (see Figure 2). A set is eligible only if it has already been initiated—that is, only if its top lesson has been successfully completed (as part of the next most general or simple set). Second, after the learner has selected an eligible set, the system automati-



The dashed line encircles one "set" of lessons.
The dashed-dotted line encircles another set" of lessons

Figure 2. The Elaboration Structure of lessons in a course: lessons are naturally grouped into sets.

cally displays the lessons (within that set) which have not yet been completed. Another menu function could indicate which lessons have been completed as well as which ones have not.

5. *Review a within-set expanded epitome of lessons already completed.* After the learner has decided on a lesson, the system would automatically present a special review of the content which the learner has mastered within the set of lessons of which that lesson is a part. This review is an expanded epitome similar to the one for whole sets (see Step 3 above), except that the content from unfinished sets has not yet been integrated into it. It is a review because this same expanded epitome was previously presented to the student at the end of the last lesson that the learner mastered in this set. The major purposes of this review are to effect periodic recall of previously learned content, to remind the learner of the meaningful context of the to-be-learned content, and to activate memory of relevant learning prerequisites that have recently been taught and mastered. This could be accomplished by reviewing the results of a game that the learner completed earlier, perhaps with emphasis on the strategies that the learner used.

6. *Complete the lesson.* The lesson is comprised of the following activities:

a. *Complete the lesson introduction.* The lesson introduction is intended to motivate the learner and to provide an indication of the nature of what is to be learned. An inquiry approach, an audiovisual sequence, a simulation, a game, and a mini-epitome are all examples of different (although not mutually exclusive) techniques that could be used, depending on the objectives of the lesson (i.e., the nature of the content and the desired performance level).

b. *Complete each of the lesson ideas.* The primary instruction takes place here. This part of the lesson should probably be about forty-five minutes long, with total lesson length not to exceed one and a half hours. Lesson content is probably comprised of concepts, principles, and procedures. If, as is usually the case, the lesson objectives call for learning these ideas at the application level, then a generality, some instances of the generality, and practice in applying the generality to new instances (plus feedback for the practice) should all be available to the learner for each such idea. In accordance with the Component Display Theory described above, learner control—the way to adapt the instruction to individual differences— would best be facilitated by a special learner-control keyboard similar to that used on the TICCIT System (see Merrill, Schneider, and Fletcher 1980; Reigeluth 1979). This learner-control keyboard would have a "generality" button, an "instance" button, and a "practice" button, plus "easy" and "hard" buttons for selecting the difficulty level of the instances and practice items. In addition, there would be an "advisor" (with an "advisor" button) that would provide the learner with advice about learner-control strategies whenever the student requested it and whenever the student's strategy was not working well. The advisor would construct an optimal learner-control strategy for an individual learner on the basis of the learner's abilities, cognitive styles, and previous performance. That optimal pattern would then provide the basis for the advisor to generate advice to the learner on learner-control strategies and on learning strategies in general. As an "intelligent" advisor, it would be able to modify its advice on the basis of student performance data or cognitive style/aptitude test results.

The ideas within a lesson would be sequenced automatically for the learner, with the sequence being based largely on learning prerequisites and other kinds of relationships (*e.g.*, meaningful vs. rote—Mayer 1975) which have optimal sequences associated with them. However, the learner would be able to go back to a previous generality or to request the next generality whenever ready. These capabilities could be effected with "last generality" or "next generality" buttons on the learner control keyboard.

c. *Complete the lesson summarizer and synthesizer.* After the last generality has been studied, pressing the "next generality" button would automatically display a summarizer. In the elaboration theory of instruction, a summarizer is a concise statement of each generality that has been taught. It is intended to provide review, but it also helps bright students discover relationships among the ideas that have been taught. After studying the summarizer, pressing the "next generality" button would display a *synthesizer*. In the elaboration theory of instruction, a synthesizer is a strategy component which explicitly teaches important relationships among the ideas—in this case, among the ideas taught in the lesson. It uses generality, instance, and practice components for teaching those relationships.

In addition to such automatic display of summarizers at the end of a lesson, the learner would be able to request a summarizer at any time. The requested summarizer would include a concise statement of all generalities in the lesson—even those not yet studied—but those generalities which have been studied would appear in a different color from those not yet studied. A "review" button could be included in the learner-control keyboard to implement this.

d. *Complete the lesson test.* A "test" button would access the lesson test, which would be similar in logic to the tests on the TICCIT

System (*see* Merrill, Schneider, and Fletcher, 1980). Alternate versions of the test would allow retakes if the learner did not reach mastery the first time. Diagnosis and prescription would accompany any failure to pass the test. This test would assess understanding of relationships among ideas as well as of the individual ideas.

7. *Complete the individual new within-set expanded epitome*. After the new lesson content has been successfully learned, it should be integrated with previously learned content. The elaboration theory prescribes an *expanded epitome* to do this. An expanded epitome is similar to a lesson summarizer and synthesizer, except that it reviews and interrelates content taught in different lessons. A *within-set* expanded epitome reviews and interrelates content from all previously taught lessons within a given set. Since the lessons within a set may usually be learned in any order (except that the one that is more general or simple must be mastered before any of the others may be accessed), the videodisc system must be able to present any of a number of versions of expanded epitomes. Naturally, instances and practice, as well as generalities, should be provided on the synthesis level.

8. *Complete the within-set synthesis test*. As soon as a whole set has been completed, the learner would take a synthesis test that would test all of the set content on the synthesis level. Again, alternate versions would be available, and diagnosis and prescription would accompany any failure to reach mastery.

9. *Complete the new among-set expanded epitome*. After a whole set has been completed, all of its content would be integrated with content from all previously completed sets. The elaboration theory also prescribes an expanded epitome to do this, only this *among-set* expanded epitome is much more comprehensive than the within-set one. The synthesis-level instances and practice might entail the use of games and/or simulations.

10. *Complete the among-set synthesis test*. After an *among-set* expanded epitome has been completed, the learner would take a synthesis test that would cover all of the content reviewed and synthesized in that expanded epitome. Again, alternate versions, diagnosis, and prescription would be provided for any learners who failed to reach mastery.

11. *Go to Step 4, or log off*. At this point, the learner could continue on to a new lesson (see Step 4 above) or could stop for the day. In the case of a school videodisc system, a record of learner performance and progress would automatically be stored in the connected minicomputer, and the learner's advisor or teacher would review it regularly. In the case of a home system where the student is taking the course for credit, learner performance would either be recorded on a magnetic strip at the center of the disc (which would then be transferred to the school minicomputer at the school library), or the learner would take all tests under supervision at the school library (or a combination of both).

Hardware and Software Recommendations. It is beyond the scope of this discussion to present a detailed description of the hardware and software. The above description provides a fairly good indication of the specifications that must be met by both. It is envisioned that the hardware and software would be extensions of those presently on the TICCIT System. In addition, the TICCIT System has specialized software for authoring instruction. It is envisioned that courseware production centers would use an extension of such software for production of courseware for videodiscs. The TICCIT System (which presently has both video and audio capabilities—although both are somewhat cumbersome and inflexible) could, in a future generation of the system, be used for formative evaluation and revision of the courseware before it is mastered and produced on videodiscs. Schneider (1976) has emphasized the need for such a modifiable system with which to design, evaluate, and revise instruction before it is mastered on the videodisc.

Section Summary

Of all the factors inhibiting the widespread introduction of intelligent videodisc systems into education, the lack of high-quality courseware is broadly recognized as the most significant. This section has presented three sets of recommendations for helping to solve this formidable problem: (1) *make better use of present knowledge* about instructional design, including (a) funding-agency support and design-specialist training seminars to facilitate the production of videodiscs from scratch, and (b) instructional-theory-based evaluation and revision by design specialists of existing educational materials which are to be used for videodisc production; (2) *further develop knowledge* about instructional design, including (a) the development of a few basic models of instruction that integrate knowledge within each strategy type (plus adjustments for each basic model) and (b) the development of meta-models to integrate models of each strategy type for different sets of goals, conditions, and constraints; and (3) *design hardware and software* that will most facilitate the presentation of high-quality courseware, including a special learner-control keyboard that allows learners to select what to learn (content components), as well as how to learn it (strategy components).

Conclusion

We began by describing the feeling of qualified enthusiasm that pervades the literature on instructional videodisc systems: enthusiasm for the remarkable potential of videodisc technology for education, qualified, however, by the very serious challenge posed to instructional designers and educators in general to make the most of this new technology.

The problem that Hirschbuhl (1977) describes is that of the resistance to change provoked in those who are asked to change when the advent of some innovation requires that they modify comfortable, familiar ways of doing things. One strategy for overcoming such resistance is educating people about the benefits to be gained by adopting the innovation. It is hoped that this discussion has served to inform, and perhaps even excite, more people about the great potential of videodisc technology.

Schneider addresses an equally critical problem—namely, the lack of proven principles and procedures for the design of videodisc instructional systems and the lack also of individuals skilled in their application. Again, it is hoped that the ideas and recommendations presented here suggest useful ways of addressing that problem and will stimulate others to turn their attention to this critical area of inquiry.

Bennion's (1974, 5) conclusion to a report written several years ago provides a fitting closing statement:

> In summary, the videodisc with random access and large capacity for storage of high quality audio-visual material has the potential of becoming a very effective new media for individualized interactive instruction at low cost. This media should be developed carefully, making use of the experience gained in the TICCIT project and the best available instructional psychology and learning theory so that the full potential of the videodisc can be realized.

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