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ABSTRACT

Arguing that the systematic application of knowledge about instruction to videodisc technology is essential if the full potential of this medium is to be realized, this paper begins by discussing the need for intelligent videodisc technology in our educational system. A brief review of the state of the art in intelligent videodisc systems, which describes their capabilities and limitations, is followed by a similar review of some aspects of instructional theory that have implications for the design of hardware, software, and courseware for such systems. Some of the problems inhibiting the introduction of videodisc into education are then discussed with emphasis on the lack of sufficient high-quality courseware. Finally, a section on new horizons suggests solutions to these inhibiting factors under the rubrics of general recommendations and recommendations for making better use of present knowledge, for the design of hardware and software, and for the development of instructional models and theories for videodisc systems. A 13-item reference list is provided. (RP)

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There is in the literature a sense both of excitement and of urgency about the use of videodiscs in education. Bork, Luehrmann and Schneider (1977) 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" (p. 3). A few paragraphs later they continue, "it is realized that hardware alone is not sufficient but that hardware sales will be driven by the availability of well-tested, effective course materials" (p. 3).

This same theme is also reflected in this paper, as an attempt is made to show how the systematic application of knowledge about instruction to videodisc technology is essential if the full potential of this medium is to be realized. Specifically, the paper will begin by discussing the <u>need</u> for intelligent videodisc systems in our educational system and will show, as Dustin Heuston (1977) does so persuasively, that "this is a propitious historical moment to work with ... the use of technology" (p.16) to solve fundamental educational problems. A brief review of the <u>state of the art in intelligent videodisc systems</u> will describe the capabilities and limitations of these systems. This section will be followed by a similar review of <u>the state of art in aspects of instructional theory</u> that have implications for the design of hardware, software, and courseware for intelligent videodisc systems, and by a look at some of the <u>problems inhibiting introduction</u> of videodisc systems into education, with primary focus on the lack of sufficient high-quality courseware. Finally, a section on <u>new horizons</u> 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. Because the emphasis in this paper 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 discussion in this paper. Consequently, references to minicomputers or CAI which do not explicitly mention videodiscs should nonetheless be understood to apply directly to videodisc instructional systems also.

The Need for Intelligent Videodisc Systems

In a paper commissioned by the National Institute of Education entitled, *The promise and inevitability of the videodisc in education*, Heuston (1977) summarized the contemporary educational situation by pointing out that standard educational institutions have failed to educate a large enough segment of the population to a high enough level that they can find meaningful jobs in this post-industrial society in which high levels of literacy and computational skills are prerequisites.

The central problem, Heuston contends, is that teachers have too much work to do and, moreover, are confronted by serious obstacles in their attempts to execute their four major tasks. First, their efforts to present needed information at a level appropriate to individual students are complicated by the wide range of ability levels and learning styles present in any one classroom. Second, their attempts to provide each student with as many trials with feedback as are necessary to achieve mastery is once again frustrated by incompatible individual and group needs. Third, the task of providing an environment in which students are motivated to learn is exacerbated, especially in inner city schools, by adverse intellectual traditions and by the effects of television. Finally, the task of passing on these skills and knowledge to other teachers is shortchanged because the first three tasks are so all-consuming.

Heuston identifies three possible solutions to such a work problem: (1) hiring more workers, (2) finding ways to make existing workers more productive, and (3) harnessing technology to do more of the work. Of these, the application of technology is the only feasible and cost-effective solution, for, as Heuston argues, not since the invention of the printing press 500 years ago have educators had available to them processes as capable of producing a quantum leap in "educational work efficiencies" (p. 13) as are available to them now with computer and videodisc technologies. To quote Heuston, "occasionally, a new technology appears which is applicable to a certain process and allows, therefore, a quantum leap to be made in the amount of work that can be done by a worker in that field" (p.11). Whereas man typically attempts to improve his efficiency by fine tuning the process currently in use, no amount of such fine tuning can produce as much of an increase in work per worker as the new process. Intelligent videodisc technology is such a new process. Moreover, as semiconductor manufacturers continue to double the number of components contained in a single 1/4 inch silicon chip, and as computer hardware, therefore, continues to drop in price, the opportunities afforded by this technology will become increasingly attractive. By 1980, "powerful computers with up to a million bits of memory will be all on one chip and will cost less than $100" (p. 16).

Hirschbuhl (1977) also underscores the need to improve student achievement without lowering academic standards, and the need to individualize instruction, in his case for a postsecondary student population which is increasingly heterogeneous due to open enrollment policies. He presents these needs--as well as the necessity of providing present and future generations of students with the computer literacy and skills required in an increasingly computerized society--as reasons for supporting computer-assisted instruction. To quote Hirschbuhl (1977): "Suffice it to say, any university not now making use of CAI, should seriously reevaluate its position with respect to this dynamic instructional aid" (p. 6).

Heuston (1977) completes his compelling portrait of the promise of technology for current educational problems by describing why computer and videodisc technology are so well suited to facilitating the teacher's work in each of the four major tasks. First, because computers can keep records of a student's progress through an instructional sequence or curriculum, computer-based instruction is admirably suited to presenting the student with accurate information at a level appropriate for him or her. Similarly, CAI has long been recognized as particularly effective for providing drill and practice exercises, with the trials and feedback necessary to achieve mastery. Moreover, the student is provided with immediate knowledge of results because there are none of the interruptions of group instruction, thereby preventing the formation of incorrect concepts and skills and allowing many more trials with feedback than could be accomplished in the same amount of time in a traditional classroom setting. Thirdly, computer-based videodisc systems enhance motivation because the student controls the pace of his or her own learning, and therefore has a greater sense of control over his or her instruction, and because the "mood" and "patience" of the computer are unchanging. Finally, such systems ensure the replicability of instructional interactions because the nature of these interactions is not dependent on a teacher's remembering them from one class to the next, nor on his or her relaying to another teacher exactly what transpired. This facilitates both the continuous improvement of instructional interactions and the sharing or transmission of those improvements nationwide.

The realization of this technological potential is, of course, attended by its own set of problems. In Heuston's words:

> But the most challenging task, as always with technology, will be to ensure that it is not misused. This may be a problem because the technology may be upon us before we are prepared. ... For this reason for the next ten to twenty years the general thrust

of educational research and development should be focused on harnessing and learning how to handle this new additional source of work. (pp. 24-25).

In other words, to make effective use of videodisc technology, further development and systematic application of principles of instruction is necessary. Moreover, as is argued below, such knowledge about instruction must be applied to the design of hardware and software for intelligent videodisc systems, as well as to the design of courseware for those systems.

One point that needs emphasis is that videodisc systems should not be seen as making teachers obsolete, any more than the wheat combine made farmers obsolete. What is envisioned is a change in the teacher's role, just as the combine effected a change in the nature of the farmer's work. The net result will be greater "yields" per teacher at lower overall costs. One aspect of this changed role is that, rather than being responsible for a subject matter, a teacher will be responsible for a group of students: the teacher will be less concerned with the subject matter--teaching--and more concerned with the student--advising and motivating. Perhaps teachers will actually be able to work on aspects of a person's development other than just the intellectual (e.g., the social, emotional, and moral aspects), which are increasingly in need of attention.

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. This section of the paper describes its most important capabilities and limitations.

Capabilities

A closer look at this point at the capabilities of intelligent videodisc systems will reveal in concrete terms why experts in videodisc technology consider it the biggest breakthrough in instructional technology since the Gutenberg press. The following is a description of its media capabilities; its storage capabilities; its motivational capabilities; its ease of use, maintenance, distribution, and replication; its cost advantages; its advantages for learner productivity and its likely second-generation capabilities.

Media Capabilities

The fact that videodiscs can incorporate all existing instructional media (namely, print, audiovisual displays, and computer-assissted iinstruction) 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. The following outline elaborates on these capabilities and some of their instructional implications.

Visual media incorporated. Textual material, transparencies, 35mm slides, filmstrips, microfilm, motion pictures, and videotape can all be accomodated on a videodisc. Schneider (1976) and Braun (1977) see videodiscs completely replacing conventional motion picture displays in educational settings, because of both the low cost and the durability of the videodisc system as a playback device. While videodisc players are comparable to film projectors in price, the anticipated purchase price of a videodisc ($10 - $15) is much less than the rental fee for a single showing of a 20-minute film ($15 - $25), let alone the $200 purchase price of a film (Braun, 1977). Moreover, because the focus here is on electrooptical rather than electromechanical videodisc systems (where the videodisc is read by a laser beam which produces no wear on the disc, rather than by a needle), videodiscs are understandably much more durable than conventional film or videocassettes, which must typically be replaced after 50 and 200-300 showings, respectively (Schneider, 1976). Not only is there no wear on the videodisc by the optical stylus, but because an objective lens focuses the light inside an outer protective plastic coating, dust, fingerprints, scratches, etc., have no effect on the playing of the disc!

According to Schneider, 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. Finally, by adding still frame sequences to existing motion pictures, literally millions of dollars worth of existing educational films, videotapes, etc., could be rejuvenated.

Audio capabilities. Currently, 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 (elementary vs. advanced) for different groups of learners. While audio is not currently available in still frame, slow motion, or reverse modes, continuous audio with still frames, as well as the availability of more than two audio tracks, are anticipated (and indeed have been engineered by groups such as Westinghouse Technical Training Operations in Baltimore, Maryland).

Modal capabilities (still/motion, speed, direction). 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" (Hueston, 1977, p. 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.) Slow motion not only allows learners to study motion sequences in detail, at their own pace, but also allows pacing to be incorporated as a feature of instruction where appropriate, for example in typing instruction. Fast forward and reverse allow students to survey material rapidly and to then concentrate on those areas in which they are most interested. Chapter stops, like tab settings on a typewriter, together with an index, also facilitate efficient movement through the disc (Hueston, 1977).

<u>Interactive, "intelligent" capabilities.</u> Random access of each of the 54,000 frames per side, made possible by electronic addressing of each of those frames, in combination with the memory and processing capabilities of computer (whether an internal or external microprocessor, or an external central processor), provide the capability of interactive, individualized instruction. Specific capabilities resulting from intelligent systems include:

1. branching, with either fixed or dynamic choices (hence, immediate knowledge of results)
2. item generation
3. testing
4. constructed response and answer analysis (matching student responses to correct/incorrect 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.

<u>Storage Capabilities</u>

The numbers here are particularly impressive. A single 30-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, each of the 54,000 tracks provides 185,625 bits of memory, for a total of 1.25 billion <u>bytes</u> per disc side. That means, for example, that the entire <u>Encyclopedia Britannica</u>, or 15 volumes each with 1,000 500-word pages, can be stored using only 4% of storage capacity of a single disc (Braun, 1977). Or again, that a mere 100 tracks of a videodisc can store 20 times as much information is a mini floppy disc, with transfer rate and average access time superior to that of the mini floppy disc by at least two orders of magnitude (that is, 7 million bytes per second vs. 16 thousand bytes per second, and 3 milliseconds vs. 463 milliseconds, respectively), while system cost, disc cost, and error rate are approximately twice as good (Braun, 1977). Also, at a compression factor of 300, a single disc can store up to 150 hours of audio.

These vast storage capabilities suggest immediate applications for data archiving, including large files of computer data, which until now could only be stored using time-sharing or batch-processing facilities (Braun, 1977). Moreover, 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.

Ease of Use

In addition to the random access capability of videodiscs mentioned above, ease of use refers to the fact that videodiscs are easy to handle (like audio LP's), may be used at a time of the learner's choosing (unlike televised instructional programs, for example), and may be located anywhere. That is, while videodisc players do not yet enjoy the same popularity as television sets, "intelligent" videodisc systems need not be interfaced to a central processor to be "intelligent" and can therefore easily be exported to various training sites--a clear improvement over conventional CAI systems.

Moreover, the ever-increasing integration capacity of microprocessors, together with the high-density storage of the videodisc, makes the whole system very compact.

Ease of Maintenance

The durability of the videodiscs themselves has already been described. What is equally appealing is the low maintenance costs of videodisc players compared to those of videocassette recorders--for example, $40 annually for the MCA Discovision Model 700 vs. $180 for a videocassette recorder (Wood, 1979). Heuston (1977) also refers to the greater complexity, expense, and unreliability of handling videotapes.

While perhaps not initially as easily distributed as books, videodiscs are much easier to distribute than films and videotapes (for example, much easier to mail), and certainly easier than traditional CAI, inasmuch as the latter is dependent on connection by cable to a central computer.

Ease of Replication

With videodiscs, as with books, motion pictures and CAI, instructional sequences are easily replicated because instruction is stored in a virtually permanent form, such that replication does not depend on an individual's remembering from one occasion to the next exactly what he or she presented in a previous lesson. Also, copies of videodiscs are stamped (like LP records) rather than recorded (like audio tapes), which makes them easier and cheaper for the manufacturer to produce but more difficult for black marketeers to produce.

Costs

In general, while material and hardware costs 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 such instruction cost-effective is selling a sufficient number of copies and ensuring sufficient use of each individual videodisc so as to spread out those high fixed costs. For example, economies of scale realizable at 1,000 copies or five or more uses per videodisc reduce the purchase cost per copy to about $2.00 and result in a cost per student hour of instruction of $.75, or roughly a cent a minute (Bennion in Heuston, 1977). At this price, each student could have his or her own copy.

More specifically, cost considerations may be broken down into costs for materials, hardware, development, production (i.e., mastering and replication), and systems operations and maintenance. While the following review is far from exhaustive, it should reflect the variety of factors that need to be considered in a cost analysis. It draws extensively on the cost models developed by Bennion and Schneider (Heuston, 1977), which cut a path through what might otherwise have been an unintelligible maze.

Material costs. According to Wood and Stephens (1977), the costs of materials for producing videodiscs are very low, constituting only about five per cent of the total disc price, as compared to the material costs for producing videotapes, which make up 90 per cent of total tape costs.

Hardware costs. Schneider (1976) points out that while an optical videodisc player and color monitor ($900) are more expensive than a 16 mm ($825) or 8 mm ($554) projector and screen, it is nonetheless the cheapest of the video playback systems--a 3/4 inch videocassette player and monitor, for example, costing about $1,500. Also, Hirschbuhl (1975) argues that hardware costs should be less than the costs of courseware development because of the expected long life of each of the components of an intelligent videodisc system (videodisc player, color monitor, interactive keyboard, and minicomputer).

Mastering and replication costs. According to Braun (1977), it costs $1,000 to produce the videodisc master and $1 for each additional copy, so that a run of 200 discs would result in a cost per copy of $6, a run of 1,000 discs would reduce the cost per copy to $2, etc.

Development costs. Included here are the costs of designing, authoring, and producing the intermediate media needed to master the final videodisc, including the costs of the authoring hardware. Although this is certainly one of the most expensive parts of videodisc instruction, there are nonetheless offsetting factors. Heuston (1977), for example, explains that it is possible to produce a broad array of instructional materials from the authoring of a single, completely original videodisc (that is, from production involving new motion and still frame sequences), thereby enhancing the possibilities for a profitable return on investment. Hirschbuhl (1975) suggests that authoring costs can be reduced by working first with existing computer-based courseware. Bennion (Heuston, 1977) points out that the number of still frames is a critical factor in development costs. While still frame sequences are more expensive to produce than motion sequences, and therefore increase the production costs of videodiscs, the cost per hour of instruction remains relatively constant because still frames increase the length of instruction. Bennion recommends that a cost analysis be conducted before authoring begins to determine the number of still frames appropriate for a particular instructional sequence, and he provides a model for calculating that number.

Cost per student hour of interactive videodisc instruction. Bennion and Schneider also 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 per cent of the disc devoted to still frames). Bennion demonstrates that "when more than about 15 to 20 per cent of the disc is devoted to still frames, the cost of instruction per hour is essentially constant" (Heuston, 1977, p. 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 1,000 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, p. 91). For example 100 discs each used 100 times, or 10,000 discs each used once, results in an hourly cost per student of about $.75, whereas 1,000 discs each used 100 times, or 100,000 discs each used once, produces an hourly cost of less than $.10!

Operations and maintenance. While intelligent videodisc systems need not be connected to a central processing unit to be "intelligent," Hirschbuhl (1977) emphasizes that the costs of systems maintenance, operations, and program adaptation for an on-line system are substantial. However, both he and Schneider (1976) expain that computing costs can be reduced by storing on the videodisc itself both instructional sequences and the computer programs needed to execute those sequences, thereby reducing the storage and processing capacity required of a minicomputer.

Benefits. In addition to the cost advantages realizable when videodiscs enjoy widespread distribution and utilization, Hirschbuhl 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 should surpass that normally obtained with books or motion pictures, and it should equal or exceed that obtained with CAI systems. Moreover, the use of videodisc systems in continuing and in-service or on-the-job education should markedly improve learner productivity by eliminating time normally spent travelling to the learning center.

Second-generation Capabilities

Current emphases in research and development for videodisc hardware include: (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), as well as greatly increasing the storage capacity of the disc because of the significant compression of information possible with digital storage; 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 muiltiple 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!

It is very useful to consider all of the above capabilities in terms of the various videodisc systems currently or soon to be available. Bunderson and Campbell (Note 1) have distinguished four categories of videodisc systems, (1) consumer, (2) instructional/educational or commercial, (3) intelligent, and (4) second-generation intelligent; and they have described the capabilities of each for displaying and controlling print, audiovisual media, and CAI. Without an internal microprocessor, the consumer model (Magnavox) is capable of displaying all print and audiovisual media, including two audio tracks; but control of the random access and of the display modes (e.g., whether still or motion, fast or slow, forward or reverse) is all manual, as is its limited branching capability. The I/E (industrial/educational) system, which has its own microprocessor, adds the capability of programmed random access, control of display mode, and branching (which, however, is still limited to fixed choice). It is the intelligent system, which interfaces the videodisc player with an external microprocessor, that allows for truly interactive instruction: namely, answer analysis, item generation, scoring, record keeping, etc. The microprocessor also allows the production of simple computer graphics. The capabilities of second-generation intelligent systems have already been described above.

Bennion (1974) and Hirschbuhl (1977) both describe a still higher level of sophistication in which the videodisc system is connected <u>on-line</u> to a central processing unit, thereby greatly enhancing the memory and processing capabilities of the system, although system costs would increase and ease of use would decrease because the system would no longer be stand-alone. To offset these higher communmication costs, Hirschbuhl (1977) recommends a technique called "distributive processing" (p. 86), in which multiple minicomputers, each capable of supporting many terminals, are connected to a large host computer. Finally, Bennion describes the addition of a magnetic read-record 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" (p. 3). 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 CAI systems and the heightened learner productivity that such systems produce. While perhaps not yet as convenient to use or distribute as books, videodisc systems already afford significant improvements in convenience and cost over conventional CAI systems especially when used by large numbers of learners.

LIMITATIONS

Two comments surface repeatedly in the literature concerning limitations of videodisc systems. First, videodiscs are a read-only memory medium, meaning that once the disc is pressed, it can no longer be modified. 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. Because videodiscs are not errasable and are difficult to copy (unlike videotapes), consumers will not be able to make a home recording of one, which may be a limitation for consumers but will undoubtedly be a relief to producers.

Section Summary

The intelligent videodisc system is undoubtedly the most powerful educational tool to be developed since the Gutenberg press (if not since the development of man himself!). Its media capabilities; storage capabilities; motivational capabilities; ease of use, maintenance, distribution, and replication; potential cost advantages; learner productivity advantages; and likely second-generation capabilities all indicate that videodiscs may bring about the kind of change in education that McCormack's wheat combine brought about in agriculture. In Bennion's words:

No other interactive instructional system that provides motion, color and audio is capable of operating at such low cost. The flexibility in scheduling and location plus the high quality of instruction and low cost per hour that appear to be realizable with the interactive videodisc system may permit this new technology to have a great impact on the educational environment in the near future. Although the low cost is attractive, the production of high quality interactive courseware is essential for ultimate acceptance and success of the new approach to instruction." (Heuston, 1977, p. 85).

As was mentioned above, instructional science--and only instructional science--can provide the knowledge necessary to produce the high-quality, interactive courseware that is essential for videodiscs to achieve their potential in education. The next section of this paper describes some recent developments in instructional science that have important implications, not only for the design of courseware, but also for design of software and hardware for intelligent videodisc systems.

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 methods of instruction--their effects under all kinds of conditions (i.e., for all kinds of students and all kinds of subject matter) and 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, & 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. However, the results of such investigations were highly inconsistent, primarily because there was more variation within each type of method than between different types of 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 devote most of their efforts to analyzing methods of instruction into more elementary components and to investigating 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 were found to be highly reliable (see Fleming & 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 are now recognizing the need to devote their efforts to integrating a substantial amount of existing knowledge (and to extending 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; Reigeluth, in press). The following is a brief summary of some recent work that has been done along these lines. This work has important implications for the design of intelligent videodisc hardware and software, as well as for the design of effective courseware for use on an intelligent videodisc system. Such implications will be discussed later in this paper.

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

<u>The Component Display Theory</u>

Merrill's Component Display Theory (Merrill, in press; Merrill, Reigeluth, & Faust, 1979; Merrill, Richards, Schmidt, & Wood, 1977) is intended for cognitive objectives. It is a prescriptive theory that is comprised of (1) <u>six models</u> of instruction, each of which can be used in varying degrees of richness, and (2) a unique <u>system for prescribing those models</u> 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, those requiring application, and those requiring discovery. Another difference exists between recall objectives that require verbatim recall and those that require paraphrased recall. The third and final difference lies between objectives that require recall of specific instances (or cases) and those that require 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: (1) remember an instance verbatim, (2) remember an instance paraphrased, (3) remember a generality verbatim, (4) remember a generality paraphrased, (5) apply a generality to "new" instances, and (6) discover 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) examples showing the application of that generality to instances, 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 as to 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, 1979) is the Component Display Theory's solution to the problem of individual differences among students. It requires some brief student training in (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 examples, and the practice items) to make his or her own optimal instructional design while skipping over strategy components that are not necessary. For example, rather than designing "visual" instruction for some students and "verbal" instruction for others, 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.)

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, examples, and practice) could be enriched with such secondary strategy components as (1) an alternative representation (e.g., a diagram, picture, or flow chart), and (2) an attention-focusing device (e.g., underlining, exploded diagrams, or common errors). The richest version of this model would include a large number of examples 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 (ruleg--or rule-example--as generalities and examples), 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), Markel, Merrill, and Klausmeier (strategies for teaching concepts, especially instance divergence--examples 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) is 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 also important to point out that 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 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. For more information, the reader is referred to Merrill (in press), Merrill, Reigeluth, and Faust (1979), and Merrill, Richards, Schmidt, and Wood (1977). 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 these strategy components (see Merrill, Olsen, & Coldeway, 1976, for a review). However, no research has been done 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, 1979; Reigeluth, 1980; Reigeluth, Merrill, Wilson, & Spiller, in press; Reigeluth & Rodgers, 1980; Reigeluth & 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 topics), 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 topics 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 predecessor, subsumption theory. The formation of stable cognitive structures through sucessive differentiation has been largely ignored in current instructional practice, in spite of the monumental pioneering work of Ausubel.

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 as to 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 subsumptive (or general-to-detailed) sequence is used to optimize the formation of stable cognitive structures. However, the way the subsumptive sequence is operationalized varies considerably from one type of cognitive structure to another. These operationalizations represent a significant departure from Ausubel's instructional model (while still implementing his learning theory), especially in their attention to information processing theory and to Gagne's cumulative theory of learning. Unlike the Component Display Theory's models, only one of these three models would be used for any given course.

In all three models, the instruction begins with a special kind of overview which (1) is derived on the basis of a single kind of knowledge structure and (2) epitomizes that knowledge structure rather than summarizing the course content. ("Epitomizing" means providing concrete examples and practice items, as well as generalities, for a few fundamental and highly representative topics, whereas "summarizing" means providing only abstract generalities for all major topics.) 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 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 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 (see the above-referenced papers).

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 variables 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 miltiplicative function of expectancies and values. In addition, Keller has 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, pp. 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 is taking it one step further by developing prescriptions for the motivational design of instruction (Keller, in press) and by integrating those prescriptions with models for the "cognitive" design of instruction, such as the Elaboration Theory and the Component Display Theory. 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 subsumptive 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 topics 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 gaming, management strategies, and tutorial dialogues.

It has been argued above that instructional science and only instructional science can provide 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 in the final section of 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 300 years that it took for books to become an integral part of society with the few decades within which television (50 years) and computers (30 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" (p. 1). Moreover,

> The dramatically different learning environments possible with personal microcomputers and video-disc systems, combined with the unbelievably-short-time-scale of their evolution have presented educators simultaneously with exciting possibilities for improving learning experiences for their students and with an almost insurmountable challenge to adjust their carefully-developed educational systems (evolved over ... centuries) within substantially less than a decade." (p. 2)

More specifically, Braun (1977) cites inadequate system _reliability_ and _teacher preparation_, high _costs_, _inconvenience_ (that is, size), confusion over _language_ (that is, which of ALGOL, APL, BASIC, LOGO, PILOT, or PASCAL to use and when), and lack of sufficient high-quality _courseware_ as factors inhibiting more widespread adoption of minicomputers and videodiscs in education. Braun reflects the seriousness of the courseware problem when he writes: "The single problem identified by everyone concerned with educational computing as a critical one is the lack of high-quality courseware" (p.53), and again when he quotes from a paper by Andrew Molnar entitled _National Policy Toward Technological Innovation and Academic Computing_: "Numerous national studies have all concluded that the lack of good computer-based material is the major obstacle to the widespread use of computers" (p. 53) and hence, by extension, to widespread use of intelligent videodisc systems.

Authoring costs, marketing costs (of trying to penetrate a fragmented educational market), poor management by federal funding agencies (which withdraw support just as R and D teams are getting going and before there is an adequate market for commercial publishers to take over support), and authoring efforts by individuals rather than teams are all outlined by Braun as particular aspects of the courseware problem. Two other aspects of the problem addressed by this paper include: 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 "peopleware," are state-of-the-art 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, state-of-the-art problems can all be solved. Some solutions to these problems are discussed in the final section of this paper.

NEW HORIZONS:

SOLUTIONS TO INHIBITING FACTORS

Braun (1977) describes ways in which minicomputers have significantly alleviated problems associated with system reliability, teacher preparations, cost, and size; and frther, he advocates the formation of a consumers' union for educators which would protect consumers against the competing claims of the various manufacturers in this burgeoning industry. Moreover, 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 greatest state-of-the-art problem 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: (1) recommendations for making better use of present knowledge about instructional design, (2) recommendations for the further development of knowledge about instructional design, and (3) recommendations for the design of hardware and software that will most facilitate student use of high-quality courseware.

Recommendations for Making 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 (1) the size of the market is unknown and

(2) 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 practicing 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. Bunderson (1977) recommends [illegible] 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 (Reigeluth, 1979). Such materials represent a valuable base that could be revised and added to so as to take full advantage of our current knowledge about instruction to realize the potential of the greatly increased capabilities of the videodisc.

One additional recommendation is that both the evaluation and revision of existing educational materials be based on instructional science. Instructional evaluation procedures are well-suited for empirically identifying weaknesses in educational materials, but they are grossly inadequate for prescribing revisions. Frequently, 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 an analytical evaluation, as opposed to an empirical 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, only under the condition that they partake in a training seminar prior to the project.

Finally, Braun (1977) calls for the establishment of a clearinghouse which would collect and distribute both courseware and information about program updates to teachers, to facilitate use of such materials.

Recommendations for the 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; and 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 (1) organizing, (2) delivering, and (3) managing instruction. All three of these 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 tehcnology 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 model. 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 (see above). Other areas needing similar attention include media selection, management of instruction (e.g., learner control), simulation and gaming, and 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). Perhaps there would be a "component model" (a model which is integrated with other component models to form a "basic model") for each of a small number of objectives, as is the case for the Component Display Theory. Or perhaps there would be a component model for each of a small number of conditions, such as types of students or types of content or types of constraints. Then, for any given application of a component 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. In addition, all of the component models within a particular strategy type could be integrated into a single basic model, as is being done with The Component Display and Elaboration Theories.

Synthesis among Strategy Types

In addition to synthesis within each type of strategy, attention must also be focused on synthesis among all such 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. Such meta-models would have to make provision for diverse goals (within the major goal type that it applies to) and diverse conditions (such as types of students, types of content, and types of 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 8-year-olds vs. for 20-year olds, or for physics principles vs. for 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.

Recommendations for 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.

Insert figure 1 about here

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1. Logon. Logging on with a name or identification number would automatically access records of that learner's abilities, cognitive style, 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 in the system's microcomputer. In the case of a school system, it would be stored in a connected minicomputer. Information about the learner's abilities and cognitive style 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. Select a course from the course menu. 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, literature, etc. 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 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. In 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 disc. 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 disc, that disc would then automatically present a special review of the major units of content which that learner has already mastered. Lessons are designed such that each is an elaboration of 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 of 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 serves to effect periodic review of previously learned content and to remind the learner of the meaningful context of the to-be-learned content.

Insert Figure 2 about here

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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, elligible sets are listed by level (see Figure 2). A set is elligible 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 elligible set, the system automatically 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 that learner has already 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.

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

6.1 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).

6.2 Complete each of the lesson topics. The primary instruction takes place here. This part of the lesson should probably be about 45 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 examples of that generality, and practice in applying the generality to new examples (plus feedback for the practice) should all be available to the learner for each such topic. 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, & Fletcher, 1979; Reigeluth, 1979). This learner-control keyboard would have a "generality" button, an "example" button, and a "practice" button, plus "easy" and "hard" buttons for selecting the difficulty level of the examples 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 (1) whenever the student requested it, and (2) 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 that 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.

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 he or she felt ready. These capabilities could be effected with "last generality" or "next generaltiy" buttons on the learner control keyboard.

6.3 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 to discover interrelationships among the topics 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 this lesson. It uses generality, example, 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.

6.4 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, & Fletcher, 1979). 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 ideas themselves.

7. Complete the 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 one of a number of versions of expanded epitomes. Naturally, examples 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 diagonsis 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 examples 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 review and interrelationships presented in that expanded epitome. Again, alternate versions and diagnosis and prescription would be provided for any learners who failed to reach mastery.

11. Go to step 4, or logoff. 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 clearly beyond the scope of this paper (and beyond the present state of knowledge) to present a detailed descripton 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 they are both 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 or such a modifiable system with which to design, evaluate, and revise instruction before it is mastered for disc production.

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 of the paper has presented three sets of recommendations for helping to solve this formidable problem: (1) recommendations for making 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) recommendations for the further development of knowledge about instructional design, including (a) the development of a few basic models of instruction that integrate knowledge within each strategy type (plus adjuctments 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) recommendations for the design of 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

This paper 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. Borrowing again from Hirschbuhl (1977):

> We are going through a period of trying to adjust an educational system that was designed for horse and buggy days to a jet age society. CAI (and hence intelligent videodisc instruction) is helping us to come to grips with this problem. It will not succeed as long as substantial numbers of educators prefer the short, slow travel of outmoded systems to the enlarged world of today's dawning technology. ...if they (educators) are not (adventurous), we will continue to be a society that prefers to react to crises instead of one that prefers to prevent them. (p. 31)

On a still heavier note Schneider (1976) comments:

> The major feasibility questions do not revolve around the videodisc technology, but around a still-infant instructional technology. To be really cost-effective, videodiscs must be stamped in reasonable numbers; and, therefore, a reasonable number of schools and students must agree to use them. This acceptance will not occur unless the material stamped on the disc really works, and works well. And it's not likely to work well unless it was developed and tested by people who had a pretty good idea of how to do the job right the first time. ... Until we have justifiable confidence in our instructional development procedures, we would do well to leave videodisc programming in the hands of the entertainment industry. (p. 58)

The problem that Hirschbuhl 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 peole about the benefits to be gained by adopting the innovation. It is hoped that this paper has served to inform, and perhaps even excite, more people about the great potential of videodisc technology.

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

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

> In summary, the vidiodisc 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." (p.5)

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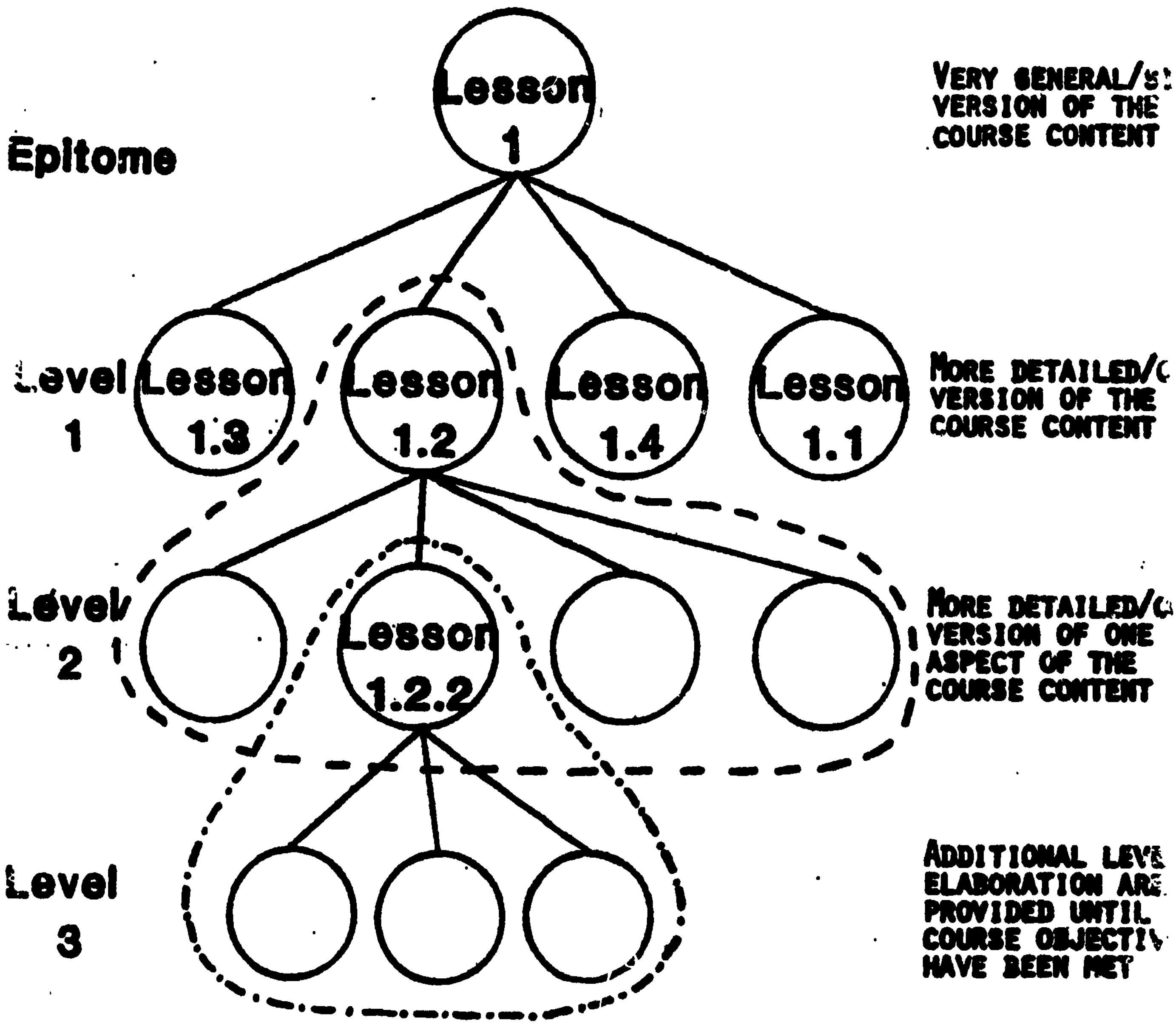
1. LOGON.
2. SELECT A COURSE FROM THE COURSE MENU.
3. REVIEW AN AMONG-SET EXPANDED EPITOME OF SETS ALREADY COMPLETED.
4. SELECT A LESSON FROM THE LESSON MENU.
5. REVIEW A WITHIN-SET EXPANDED EPITOME OF LESSONS ALREADY COMPLETED.
6. COMPLETE THE LESSON:
    - 6.1 COMPLETE THE LESSON INTRODUCTION.
    - 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 LOGOFF.

FIGURE 1. A HYPOTHETICAL SEQUENCE THAT A LEARNER MIGHT FOLLOW ON A VIDEODISC SYSTEM.



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.