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ABSTRACT

Computer based instruction (CBI) is composed of individual frames viewed one at a time. Compared to a typical textbook, CBI restricts the adult learner's capacity to access information from different parts of the lesson and to view complex presentations. Designers of CBI must compensate for these limitations by making a concerted effort to synthesize or tie together content parts, resulting in a coherent, stable cognitive structure in the learner's mind. Synthesizing strategies include: (1) using hard copy adjunct aids such as diagrams, figures, and content outlines; (2) implementing learner control features such as the menu and HELP options; (3) using graphic synthesizers such as lesson maps, diagrams, and other figures to periodically orient the learner toward the content structure; (4) using animation, graphics, sound, and timing to highlight structurally central content parts; (5) using verbal synthesizers such as analogies, stories, and advance organizers to relate content to familiar experience; and (6) providing integrated practice and other opportunities allowing the application of multiple skills to complex problems. This report concludes by relating research on CBI strategies to a framework for instructional science and discussing potential research questions. (Author/LMM)

Tying it all Together:

Synthesizing Strategies for Computer-based Instruction

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Running head: Synthesizing strategies

Abstract

Computer-based instruction (CBI) is composed of individual frames viewed one at a time. Compared to a typical textbook, CBI restricts the adult learner's capacity to (1) access information from different parts of the lesson and (2) view complex presentations. Designers of CBI must compensate for these limitations by making a concerted effort to synthesize or tie together content parts, resulting in a coherent, stable cognitive structure in the learner's mind. Six synthesizing strategies are discussed and illustrated. Greater attention to content synthesis will result in more meaningful CBI materials. Research on CBI strategies is related to a framework for a science of instruction; potential research questions are discussed.

Tying it all Together:

Synthesizing Strategies for Computer-based Instruction

The purpose of this paper is to propose some instructional strategies that can help synthesize content presented in a computer-based instructional (CBI) lesson. To explain why content synthesis is needed, and provide a background to the paper, we will first review some basic differences between CBI and hard-copy media and define "content structure." Following a description of content synthesis strategies, we relate CBI research to a broader science of instruction.

Constraints of the Medium

Amid the recent excitement generated by computers in education among educators, some concerns remain regarding the quality of CBI learning outcomes. Most CBI systems exhibit two main constraints:

1. Limited information display. Most CBI programs use a 40 or 80 column by 24 row display. In practice, a CBI frame is not much larger than the teaching machine frames used in programed instruction twenty years ago (Skinner, 1968; Markle, 1969). Human factors research has shown that reading from a CRT display is more difficult and causes more eyestrain than reading from hard-copy materials (Campbell, et al., 1981). CBI as an instructional medium is not suited to dense information display.

2. Limited frame access. Access to individual frames may be accomplished by special commands (control characters, special functions, etc.) or by a menu selection. In either case, because of the complexity of the logic and the cost of development, direct access to individual frames is extremely rare in CBI. CBI becomes less valuable as a reference source

and, to the degree that frame access is an important learner strategy, less valuable as a learning device.

Two main problems result from the constraints described above. The first problem is related to the lack of learner control over information presented (M. D. Merrill, 1973). Materials that do not allow adult learners some control over instructional events must carefully monitor and assess student learning throughout the program; in short, they must be adaptive systems (Atkinson, 1976). Otherwise, learning is likely to suffer in efficiency and, to some degree, effectiveness. Although considerable resources have been devoted to intelligent computer-aided instruction or ICAI (Walker & Hess, 1984), the development costs of sophisticated adaptive systems presently inhibit their widespread use.

The second problem has more to do with the limited display capacity of CBI systems. An essential step in CBI design is careful analysis of the content, breaking tasks down into small chunks that can be taught and tested using a frame-based system. Unfortunately, large doses of small chunks can lead to shallow, superficial comprehension of the overall subject. There can be a lack of content synthesis (Reigeluth & Stein, 1983). Concepts are often not adequately integrated together; learners lack an understanding of how things fit together. This notion of how content fits together is referred to as content structure (Merrill, Kowallis, & Wilson, 1981; Wilson, 1985). Failure to grasp the content structure, according to schema theorists (Rumelhart & Ortony, 1977; M. D. Merrill, Wilson, & Kelety, 1981), leads to rapid forgetting of the material. Conversely, as content structure is better learned, learning becomes more meaningful and stable (Reigeluth, 1983; Ausubel, 1968).

Synthesizing Strategies

What can be done to enhance meaningful learning in a CBI environment? There is, of course, no simple formula to be followed. In this paper we discuss six specific instructional strategies that can help synthesize different parts of a subject into a stable cognitive structure within the learner's mind.

1. Use hard-copy adjunct aids such as diagrams, figures, and content outlines. Figure 1 portrays a tree diagram intended for adjunct use with a CBI program. The tree diagram summarizes the essential concepts taught in the CBI lesson.

Insert Figure 1 about here

Hard-copy support materials seem to be neglected in many CBI systems. Hard-copy materials can be valuable for a number of reasons:

* Display of information frequently accessed in the lesson
* Display of figures too complex for effective CRT display
* Reinforcement of CBI content using another media
* Take-home materials to serve as reference and reminder of lesson content

Even the most sophisticated CBI environment would do well to make use of hard-copy reference materials; students often appreciate the "Look what I learned!" quality of a handout or booklet.

The paucity of hard-copy support materials in CBI packages may be a blessing in disguise for many teachers. Integrating CBI into an existing curriculum is a critical task for teachers (Salisbury, 1984). The preparation of simple support materials is an important way teachers can adapt CBI products for use in a preexisting curriculum plan. This, of course, requires some effort, but the value of adjunct materials helps make it worthwhile (Wilson, 1984).

2. Implement learner control features such as menus and HELP options. Learner control strategies include any design features that require input from the user regarding instructional decisions. Examples include options to skip a problem, receive help on a problem, backtrack to the previous frame, or move to a different lesson. Tennyson & Buttrey (1980) have shown that students can make intelligent decisions about instruction, particularly when relevant information is available to them.

Learner control features can aid content synthesis. Structurally central content can be made available on HELP selections. Allowing "scanning" by skipping practice problems can help a learner develop a preliminary schema to subsume the topic.

Allowing a variety of sequences through the lesson can make it more likely that the learner's existing cognitive structure indeed matches the assumed prerequisites of the presentation.

Allowing for learner control is the designer's way of admitting the program is not a foolproof, deterministic solution to every user's needs. Rather than expecting the program to provide all the answers, a program allowing learner control places greater responsibility in the hands of the learner to control the learning pace, sequence, and direction. Although research has clearly shown that learner control is not the cure-all for CBI design (Steinberg, 1977), prudent use can contribute to content synthesis.

3. Use graphic synthesizers such as lesson maps, diagrams, and other figures to periodically orient the learner toward the content structure. The same figure used as an adjunct aid in Figure 1 was also included in the CBI program itself. Note the relative simplicity of the diagram; more complex figures and diagram, while possibly providing more information, become unsuitable or display on a CRT screen.

Other kinds of diagrams can be very useful. Simple flowcharts can portray direction and sequence. TICCIT (Merrill, Schneider, & Fletcher, 1980) used course maps as a means of orienting learners toward the structure of the lessons.

The value of figures and pictures in hard-copy instruction has been demonstrated in research and practice (Levie & Lentz, 1982; Alesandrini, 1984). The use of a tree diagram representing the content structure can help learners acquire a hierarchy of concepts as well as improve their attitude toward the lesson (Wilson & Merrill, 1980; Wilcox, Merrill, & Black, 1981). Several researchers have offered design guidelines to maximize the effectiveness of graphic displays (Brody, 1984; MacDonald-Ross, 1978; P.F. Merrill & Bunderson, 1981). While increasing attention has been given to electonic display design (P.F. Merrill, 1982; Alesandrini, 1984), the unique problems of electronic figures and diagrams are still not well understood. The information-display constraints of electronic media require simple, direct figures that can be easily conveyed on the screen. This may account for the seeming absence of content-relevant graphics in most CBI products available today.

4. Use animation, graphics, sound, and timing to highlight structurally central content parts. Any instructional message contains more information than the learner can be expected to encode and have available for recall. Is the exact wording of a paragraph important? The specifics of an example used? The question for designers is, what parts of the presentation do we expect the learner to remember and use, and how do we communidate that intent to the learner, thus sharing the responsiility for the outcomes of instruction? One way we can "tip off" the learner to

these intentions is by presenting stated objectives: "At the conclusion of this lesson, you will be able to..." Another important way learners catch on to instructional intentions is by observing cues such as highlighting, headings, and paragraph structure. (Anderson & Faust, 1974; Duchastel, 1982). These cues should support and not detract from a clear exposition of the content structure.

The cues available to CBI designers are numerous:

a. Graphics and animation. Graphics are often used as "frills"--entertaining spots unrelated to the content of the lesson. This is a great waste of potential. Visual displays can communicate content structure. Animation, usually used for cartoon amusement, can be intrinsic to the subject matter and convey critical information (Malone, 1981).

b. Use of space. The screen layout and balance should focus on structurally important parts of the message. This can be done by careful use of white space.

c. Sound. Sound is another form of information, often used successfully as a means of performance feedback.

d. Timed presentations. The temporal order of the display can be a surprisingly effective means of cuing learners to important content elements. Graphic overlays and timed display of text can draw the learner's attention to appropriate detail while the basic frame remains the same. Properly used, timed presentations can introduce a small sense of drama and revelation to the CBI lesson.

5. Use verbal synthesizers, such as analogies, stories, and advance organizers to relate content to familiar experience. Placing unfamiliar content into a familiar context through a simple story or analogy can be both enlightening and motivating to learners (Curtis & Reigeluth, 1984). From a schema-theoretic

viewpoint, creating links of meaning between new material and existing learner knowledge makes the new material more easily recalled and more useful when it is recalled. Often, a short story or parable can effectively inform a learner of the lesson's objective without the need of a direct statement of objectives in abstract terms.

6. Provide integrated practice and other opportunities allowing the application of multiple skills to complex problems. The typical tutorial breaks down content into small chunks, completing each chunk with a practice problem or two, proceeding serially through a great deal of material. Too often, there is little cumulative learning, that is, learning based on prior learning. This problem can be partially addressed by making special efforts to allow for "integrated practice" requiring the learner to use knowledge and skills from a number of chunks in its solution. The integrated practice can take the form of a "mini-simulation" if the subject matter allows. This notion is somewhat related to Bunderson's "work models", in which increasingly detailed practice environments are provided to the learner (Bunderson, Gibbons, Olsen, & Kearsley, 1981).

Research on CBI Strategies

Although we make reference to literature in cognitive psychology, this paper is far from a psychology paper. Nor is it directly aimed at practicing instructional designers. Its audience can be termed "instructional researchers", whose research commitment lies somewhere between psychology and educational practice.

In 1961, Arthur Lumsdaine first talked about a "science of instruction":

> There is an important "middle ground" between a basic science of learning and an applied technology of educational method.... In view of the complexity of human learning, we can reasonably expect to find few universal generalizations that would hold for all classes of instructional objectives, all classes of learners, and all conditions of instruction. Rather, it seems evident that what is needed...is a series of contingent generalizations which take account of the interactions of variables... (Lumsdaine, 1961, pp. 497, 499)

This "science of instruction" has been advocated by many others (e.g., Simon, 1969, 1980; Reigeluth, Bunderson, & Merrill, 1978; Glaser, 1976), and it seems to include these features:

1. a commitment to developing prescriptive principles of the form "If you want A and you're in situation B, then do C."

2. a commitment to empirical validation of these contingent principles.

3. a commitment to economy or parsimony of theory, to maintain its utility to the practicing instructional designer.

What methods should instructional scientists employ in developing a knowledge base? Lumsdaine (1961) recommends as a research strategy several phases of factorial experimentation, with each phase building on the lessons learned of the former. We would add that experimental research must itself be balanced with careful model-building, hands-on tryout by practicing designers, and borrowing of existing methods that have stood the test of time (MacDonald-Ross, 1978, 1979).

Research in CBI strategies is almost an ideal setting in which to test developing instructional theories. Because of the highly controlled nature of CBI, and because of its flexible data-gathering capacity, strategies can be systematically examined and evaluated. The product of such research may not be a single comprehensive system of principles, but instead a rather disjointed set of guidelines and rules applicable in limited contexts. In any case, instructional researchers will be able to provide some much-needed guidance to practicing designers who are presently working feverishly to bring products to market.

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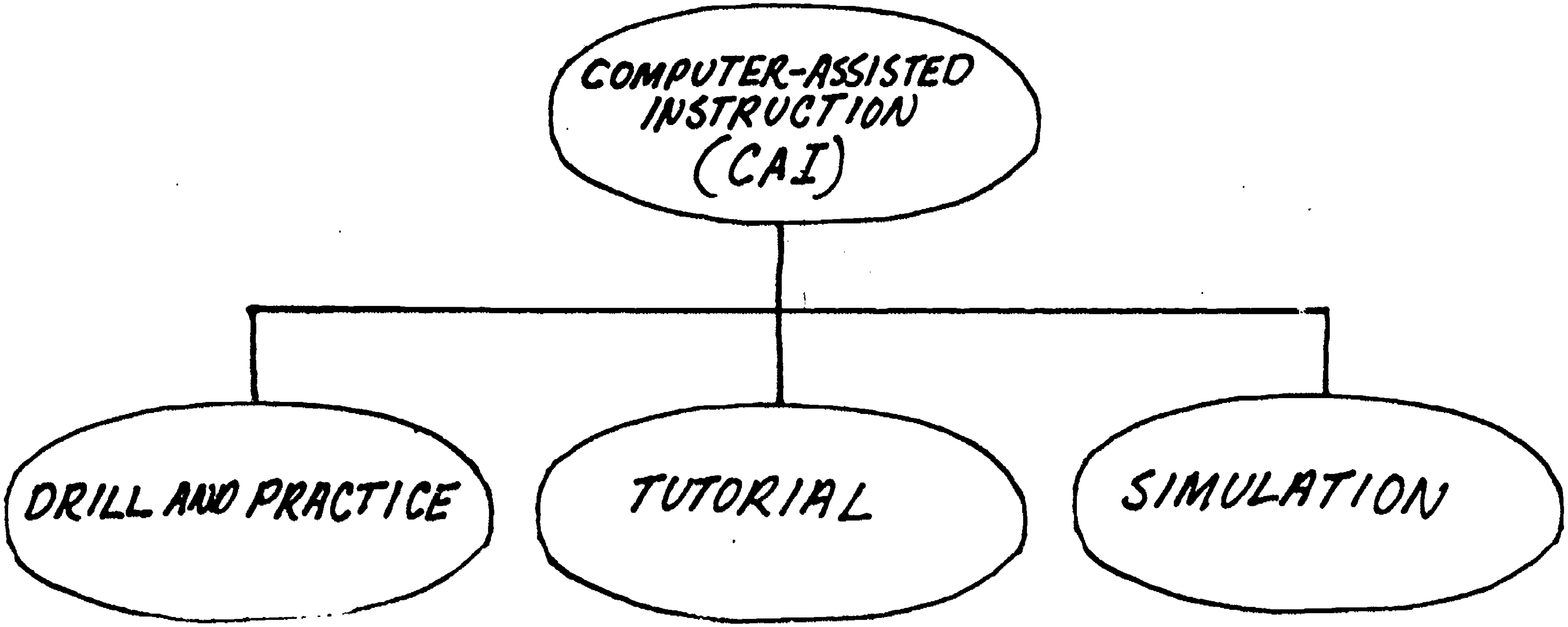

Drill and Practice

- Overlearning Basic Skills
- Multiple Discrimination
- Paired Associates

Tutorial

- Rules
- Procedures
- Concepts
- Principles

Simulation

- Problem Solving
- Decision Skills
- Skills Integration
- Motivation

Figure Caption

Figure 1. Tree diagram showing content structure for use as an adjunct aid to a CBI lesson.