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ABSTRACT

The Time-Shared Interactive Computer-Controlled Information Television (TICCIT) system represents a considerable technological advance over previous CAI systems, primarily because of its unprecedented foundation in instructional theory. This paper briefly describes the theory-base of the TICCIT system; it summarizes some recent advances in instructional theory for sequencing and synthesizing related parts of a subject matter; and it describes three major implications of those advances for the design of future theory-based CAI systems. These implications concern (1) the selection of content; (2) the use of strategies for sequencing, synthesizing, and summarizing; and (3) the provision of knowledge necessary for the learner to make good strategy decisions. (Author)

TICCIT TO THE FUTURE: ADVANCES IN INSTRUCTIONAL THEORY FOR CAI

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This is a prepublication draft. The author would appreciate any constructive criticism of this paper.

Abstract

The TICCIT system represents a considerable technological advance over previous CAI systems primarily because of its unprecedented foundation in instructional theory. This paper briefly describes the theory-base of the TICCIT system; it summarizes some recent advances in instructional theory for sequencing and synthesizing related parts of a subject matter; and it describes three major implications of those advances for the design of future theory-based CAI systems. Those implications concern (1) the selection of content, (2) the use of strategies for sequencing, synthesizing, and summarizing, and (3) the provision of knowledge necessary for the learner to make good strategy decisions.

TICCIT TO THE FUTURE: ADVANCES IN INSTRUCTIONAL THEORY FOR CAI

The TICCIT system (Time-shared Interactive Computer-Controlled Information Television, jointly developed by the Mitre Corporation and Brigham Young University) represents a considerable technological advance over previous CAI (computer-assisted instruction) systems for several reasons, the most important of which is its unprecedented foundation in instructional theory. However, TICCIT represents what will soon appear to be only a primitive first step in the development of instructional-theory-based CAI systems.

First, this paper briefly describes TICCIT's theory base. Then it summarizes some recent advances in instructional theory regarding the sequencing and synthesizing of subject matter. And finally, it discusses three major implications of those advances for the design of future theory-based CAI systems.

TICCIT'S THEORY BASE

At the time that TICCIT's software was being designed at Brigham Young University, M. David Merrill was developing a theory for instructional strategies which relate to the teaching of a single concept, principle, procedure, etc. (Merrill & Boutwell, 1973; Merrill, Richards, Schmidt, &

Wood, 1977; Merrill & Wood, 1974, 1975a, 1975b). Such strategies have come to be called presentation strategies, and they include such strategy components as generality, examples, practice items, and "helps". (Helps make it easier to understand each of the other strategy components by relating the generality to an example, point by point, or by relating an example or the solution to a practice item to the generality, point by point.) Each of these strategy components could in turn be broken down into its components. For instance, examples (1) should be divergent on variable attributes, (2) should have nonexamples that are matched on variable attributes to the examples, (3) should have attribute isolation, and (4) should use a variety of representation forms.

The result of these simultaneous activities was the design and development of the first important theory-based CAI system. The instructional displays were divided into different types based on Merrill's theory--generalities, examples of each generality, practice on the use of each generality, helps on each of those three types of displays, and three categories of difficulty on the examples and practice. The system was designed with a special keyboard that enables the learner to select any one of the types of displays (i.e., strategy components) whenever s/he wants.

In this way, the learner is given control over the timing and quantity of each presentation strategy component. This not only gives the learner access to the kind of instructional display that s/he needs at any moment, but it also teaches the learner good learning strategies that s/he can use to great advantage off line. For a more in-depth description of TICCIT and its theory base, see Merrill, Fletcher, and Schneider (in press).

ADVANCES IN INSTRUCTIONAL THEORY

Through joint funding from Brigham Young University and the Navy Personnel Research and Development Center, Reigeluth and Merrill have been working for the past year on further developing their theory on strategies for structuring (i.e., for selecting, sequencing, summarizing, and synthesizing) related parts of a subject matter for instruction. It is beyond the scope of this paper to provide more than a brief summary of this <u>elaboration theory of instruction</u>. For a more in-depth description, the reader is referred to the recent progress report on the project (Reigeluth, Merrill, et al., Note 1).

As a part of their elaboration theory, Reigeluth and Merrill have developed a model for sequencing and synthesizing the related parts of a subject matter. First, the instruction should begin with an epitome, which provides a general overview of the major parts of the subject matter and of the major relationships among those parts. Second, the instruction provides an elaboration on each of those parts, which adds detail or complexity to the general understanding of each. Third, at the end of each elaboration, the instruction provides a synthesizer, which shows the important relationships among the sub-parts comprising the elaboration and which shows the context of the elaborated part within the epitome. Fourth, after all the elaborations have been presented and synthesized, the instruction provides an expanded epitome, which shows the important relationships among the parts of the different parts of the epitome (i.e., between a part of one part and a part of a different part). Fifth, the instruction provides second-level elaborations--which elaborate on elaborations rather than on the epitome--if such is necessary to bring the student to the depth of understanding specified by the objectives of the instruction. And sixth, the instruction provides a) a synthesizer after each second-level elaboration, b) an expanded epitome after all the second-level elaborations on a single elaboration, and c) a terminal epitome at the end of the instruction.

The nature of the epitomes and synthesizers is dictated by the type of orientation structure which is selected on on the basis of the goals of the course. There are three types of orientation structures: conceptual, theoretical, and procedural.

Conceptual orientation structures show superordinate/coordinate/subordinate relations among concepts. There are three important types of such structures: parts taxonomies, which show the concepts that are components of other concepts; kinds taxonomies, which show the concepts that are varieties of other concepts; and matrices, which are the crossing of two taxonomies.

Theoretical orientation structures show cause-and-effect relations among concepts. There are two important types of such structures (often referred to as models): those which describe natural phenomena, which are invariant; and those which describe ways to achieve some end, which are goal-oriented and therefore vary as goals vary.

Procedural orientation structures show procedural relations among event concepts. There are also two important types of such structures: those which show procedural-prerequisite relations, which specify the order(s) for performing the steps of a single procedure; and those which show procedural-decision relations, which describe the factors necessary for deciding which alternative procedure or sub-procedure to use in a given situation.

Supporting structures are similar to orientation structures except that they are much smaller in scope and are nested within a single part of an orientation structure. Supporting structures may be conceptual, theoretical, procedural, or learning structures. Learning structures show the learning prerequisite for concepts and principles in the other three kinds of structures. In addition, a list may be used as a supporting structure when there is a linear relation among concepts.

IMPLICATIONS FOR CAI

One of the greatest deficiences that have been encountered on both the TICCIT system and the PLATO system, as well as in other types of modular instruction, is the problem of "splintering" or lack of synthesis and integration of the modules or segments of instruction. The recent advances in instructional theory outlined above hold much promise for solving this problem.

A radically different function for subject-matter structure is described above. Instructional designers for CAI, like those for other media of instruction, have traditionally thought of subject-matter structure as a framework for guiding the design of instructional sequences. But the above-described theory views it as that plus a lot more. Structure should itself be taught. It should be a part of the instruction in order to teach the important interrelationships within a subject matter. Including such interrelationships in the instruction should solve the problem of splintering and should help increase the student's long-term retention, transfer, and motivation.

Accordingly, future CAI systems should teach structure along with the modules in a manner similar to that described above: begin with a general epitome, continue with alternating elaborations and synthesizers, and end with a complex epitome. But the implications of this instructional model go beyond considerations for the design of the instruction on CAI; they call for a different design of the CAI system itself.

The remainder of this paper discusses three important implications for the design of future theory-based CAI systems: (1) the CAI system should provide a large degree of learner control over the selection of content; (2) it should provide learner control over components of the other kinds of structural strategies (i.e., sequencing, summarizing, and synthesizing strategies); and (3) it should provide the learner with the kinds of knowledge and information necessary for him/her to make good decisions.

Learner Control Over Selection of Content

As CAI systems start entering homes as well as schools, learners are going to demand increasing capabilities of CAI to provide learner control over the selection of content without cumbersome and demotivating "bottom up" sequences being forced on them. It will also become increasingly important that the instruction be designed in ways that are more motivational and enjoyable for the learner. The above-mentioned advances in instructional theory for synthesizing and sequencing hold much promise for meeting these needs.

Some aspects of the elaboration theory of instruction facilitate learner control over content, while others impede it. A good analogy (for showing the implications of the elaboration theory of instruction for learner control over the selection of content) is the use of a zoom lens to take a look at a painting. A person usually starts with a wide-angle view, which shows the major parts of the painting and the major relationships among those parts (e.g., the composition or balance of the picture). The person can then zoom in on whichever part of the picture that interests him/her. Zooming in one "level" allows the person to see the major subparts of that part and the major relationships among those subparts. This again provides a basis for the viewer to select whichever subpart most interests him/her for zooming in for more detail. If s/he reaches a point where s/he is no longer interested in more detail on a part, the person could zoom back out to a point where s/he is interested in more detail on one of the parts.

In a similar way, the elaboration model starts on a very broad, general level and gradually divides it into parts and the parts into parts. This approach provides the learner with sufficient knowledge to be a basis for selecting content; and the general-to-detailed organization allows the learner to learn what s/he wants to learn without having to go through a series of learning prerequisites that are on too low a level of detail to interest him/her much at this point anyway. As [illegible] becomes interested in more detail, s/he will want to learn those detailed prerequisites because s/he will see and understand their importance for learning the detail that interests him/her.

But how should this influence the design of future CAI systems? <u>First</u>, it requires software and a keyboard that will allow the learner to select any part of a lesson for further elaboration. Something like the TICCIT map structure should work fairly well if instruction was provided at all map levels instead of just at the bottom level (but the nature of the contents of the maps would often be very different--each lower level would be parts of the boxes on the next higher level). <u>Second,</u> it will require software that will provide expanded epitomes that are expanded only on the parts that the learner has selected for elaboration.

But both of these characteristics are more complex than they may at ~~first seem.~~ When a person looks at one part of a picture in detail (through the zoom lens), this is likely to influence what s/he "sees" in the subsequent parts of the picture. Such <u>elaborative dependence</u> is an extremely important factor for instruction; in order for instruction on a part to be most effective, the related parts that a learner has already studied should usually be taken into account in the design of that part. This somewhat impedes the design and implementation of instruction for learner control over the selection of content--but not insurmountably. This is where the special capabilities of CAI come in. CAI can keep track of what the student has studied and can modify each subsequent elaboration, and even the synthesizers, accordingly.

You have probably noticed that learner control over the <u>selection</u> of content implies a certain amount of learner control over the <u>sequencing</u> of content. Since these two types of structural strategies are so interrelated, it would be helpful now to discuss the implications of the advances in instructional theory for sequencing, summarizing, and synthesizing strategies.

Learner Control Over Other Kinds of Structural Strategies

To continue the zoom lens analogy, the viewer could be given control over the order in which s/he looks at parts of the picture, regardless of whether or not s/he had control over entirely skipping certain parts. The viewer could zoom in first on those parts of the picture that interest him/her most. The viewer may choose to zoom in very little before zooming back out to the wide angle view to see the context of the slightly more detailed part of the picture. (This is equivalent to learner control over frequency of synthesis as well as over type of sequence.) Or the viewer may continue to zoom in for even greater detail on that same part of the picture. And, if the viewer chooses to zoom back out right away, s/he could continue to take short zoom-ins on all the parts of the whole picture before taking longer zoom-ins on any single part.

One can readily see that the possibilities for the viewer, as for the learner, are almost infinite as to different patterns that could be followed. Unfortunately, up to now the zoom has hardly been used at all in instruction. Most sequences begin with the lens zoomed all the way in at one corner of the picture and proceed--with the lens locked on that level of detail--to systematically cover the entire scene. This has had unfortunate consequences both for integration and for motivation.

Again the question arises as to how these notions of sequencing, summarizing, and synthesizing should influence the design of future CAI systems. First, experience on the TICCIT system shows that learner control over strategy components is beneficial--for affect and motivation, as well as for effectiveness and efficiency. Therefore, a special keyboard, similar to the one for learner control over presentation strategies, should be created to give the learner control over some strategy components for these three types of strategies. For instance, this keyboard could allow him/her to refer back to the epitome at any time, it could allow him/her to see a summarizer at any time (i.e., a concise statement of all the generalities s/he has studied in that elaboration up to that time), and it could allow him/her to select any part of the epitome--or of an elaboration--for further elaboration. Second, to handle variations in sequencing, software must be created to solve the problem of elaborative dependence. The computer should vary many elaborations somewhat depending on what elaborations the student has and has not already studied.

However, even with this ability to overcome the problem of elaborative dependence, there are certain facets of sequencing content that should not be open to learner control. If the purpose of the instruction is the efficient performance of a procedure, there is a certain sequence that will optimize learning (see Reigeluth, Merrill, et al., Note 1). And to a lesser extent, if the purpose of the instruction is the attainment of a certain depth and breadth of understanding of related principles, there is also a specific sequence that will optimize learning (see Reigeluth, Merrill, et al., Note 1). But if the purpose of the instruction is an understanding of the basic concepts in a field, then the sequence is not nearly as important as long as it follows some kind of a top-down pattern (i.e., general-to-detailed sequence). Elaborative dependence is also minimal for such a conceptual approach. In other words, if a procedural or a theoretical orientation structure is used, then learner control over both content and strategy components will often be inadvisable; whereas if a conceptual orientation structure is used, then learner control over both content and strategy components should have no detrimental effects.

The conceptual orientation structure is basically a "general education" approach to a subject matter and is the approach for which learner control over content would be most important. Procedural and theoretical structures could also be nested within the conceptual orientation structure, such that the learner could decide whether and when to study each such nested type of content; but once s/he decided to study one of these nested components, his/her selection and sequence of content within that component would be fixed, although it would still follow the elaboration model pattern.

However, even in cases for which there is an optimal sequence for all learners to follow (i.e., for procedural and theoretical structures) there may be many circumstances in which the benefits from learner control over content would outweigh the costs of a non-optimal sequence, particularly if the learner were given information about optimal sequences so that s/he would not vary too far from the optimal. This leads us to the third implication of elaboration theory for CAI: the CAI system should provide the learner with the kinds of knowledge and information necessary for him/her to make good learner-control decisions.

Knowledge for Effective Learner Control

For accommodating individual differences, we have just advocated giving the learner control over the selection of different strategy components rather than having different "tracks" for different types of students. We advocate this even if research shows that a certain strategy is always best for a certain type of student for the following reasons: (1) if the student characteristic cannot be changed--such as certain kinds of aptitude--it is important for the student to learn which strategies are best for him/her and (2) if the student characteristic can be changed--such as a poor learning strategy--it is much more important to improve it than to provide an instructional strategy (or method) that minimizes that shortcoming. CAI systems, like all instructional systems, should have built-in programs for improving such student characteristics.

We mentioned above that experience on the TICCIT system shows that learner control over presentation strategy components is beneficial--for affect and motivation, as well as for effectiveness and efficiency. But in order to be maximally beneficial, the learner must know (1) the nature of the contents of each strategy option and (2) the nature of the effects on learning of each of those options (e.g., a help, some more practice, a harder example). Without such knowledge, learner control may actually be detrimental. With such knowledge, the student makes far better decisions than any "program" ever could about whether s/he, upon doing a practice problem wrong, should rework the practice problem, look at the practice help, look at an example, or just go on to another practice item.

We anticipate that the same will be just as true for learner control over structural strategies; that the learner must know (1) the nature of the contents of each strategy option and (2) the nature of the effects on learning of each of those options. (This notion is not unique to learner control. Students would also learn better from textbooks if they were given instruction in optimal learning strategies for learning from texts.)

But how can this be applied to CAI? The knowledge that the learner needs for effective learner control has two components, which should be provided in two different ways. First, the nature of the contents of each strategy option could be taught in an introductory module on the CAI system. This is a concept-classification task that should be taught with generalities, examples, practice, summarizers, etc. Second, the learner needs to learn when to use each of those strategy options--i.e., what each contributes to learning and what kinds of learning problems each can solve. This can be implemented in two ways: (1) teach some rules for the use and effects of each option in a second introductory module (complete with generalities, examples, practice, summarizers, etc.) and (2) provide an "advisor" program to give advice to the learner.

The advisor could provide advice under two conditions: (1) whenever the student requests it with a special learner control button (as on the TICCIT system) and (2) whenever both a) the student's strategy is found to be ineffective and b) the student is varying from the rules for effective use of the strategy options. The advisor program must keep track of the pattern of use of strategy options and compare it against an "ideal" created from the rules. Deviations from the ideal should be analyzed as to which rule(s) is(are) violated and make corresponding recommendations. Some parts of error analyses on a student's practice items and tests could also be used as a basis for advice to learners.

But perhaps the "ideal" pattern of use of strategy options will vary from one learner to another. CAI has a unique capability for accommodating this probability. The error analyses on a student's practice items and tests could be used as a basis for changing the "ideal" pattern for different learners and for different conditions for each learner. Also, some student "aptitudes" (see Cronbach & Snow, 1977) may provide a reliable basis for modifying the advice for each learner; but care must be taken to periodically monitor changes in those aptitudes and to update their inputs to the advisor for each student.

SUMMARY

The future of CAI lies in instructional theory-based systems because of their greater effectiveness and efficiency. The major problem in the development of such systems has been that instructional theory was insufficiently developed for theory-based systems to make much difference. But recent advances have changed this situation, and continued progress in the development of instructional theory holds even more promise for the future.

First, we briefly described the theory base of the TICCIT system, which is the first important theory-based CAI system. Its theory base is in the area of presentation strategies, and it was implemented with a special keyboard providing learner control over the timing and quantity of certain presentation strategy components: primarily generalities, examples, practice, and helps.

Then we summarized some recent advances in instructional theory for sequencing and synthesizing related parts of a subject matter. The elaboration theory of instructi n includes the use of such strategy components as an epitome, elaborations on that epitome, synthesizers on those elaborations, an expanded epitome, second-level elaborations, synthesizers for those second-level elaborations, and a terminal epitome. The nature of the synthesizers and epitomes depends upon the type of structure being taught: conceptual, theoretical, or procedural. These strategy components can be used in ways similar to the use of a zoom lens for viewing a picture.

Finally, we described three major implications of those advances in instructional theory for the design of future theory-based CAI systems. First, the CAI system should provide a large degree of learner control over the selection of content. Second, the system should provide learner control over components of sequencing strategies, summarizing strategies, and synthesizing strategies. And third, it should provide the learner with the kinds of knowledge and information necessary for him/her to make good decisions. This knowledge and information could be provided (1) in introductory modules which teach the learner a) the nature of the contents of each strategy option and b) rules about the effects and use of each of those options, and (2) in an advisor program which gives both solicited and unsolicited advice to the learner.

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