DOCUMENT RESUME

ED 285 566 IR 012 772

AUTHOR Wilson, Brent G.
TITLE Computers and Instructional Design: Component Display Theory in Transition.
PUB DATE Feb 87
NOTE 17p.; Paper presented at the Annual Convention of the Association for Educational Communications and Technology (Atlanta, GA, February 26-March 1, 1987). For the complete proceedings, see IR 012 723.
PUB TYPE Information Analyses (070) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Artificial Intelligence; *Computer Assisted Instruction; *Educational Theories; *Instructional Design; *Models; Outcomes of Education; Programed Instruction
IDENTIFIERS AECT Research and Theory Division Meeting; *Component Design Theory; Learner Control

ABSTRACT

Component display theory (CDT) is used as a working example in this examination of the relationship between instructional design theory and computer assisted instruction (CAI) models. Two basic approaches to instructional design--the analytic and the holistic methods--are reviewed, and four elements of CDT are described: (1) content types, including facts, concepts, procedures, and principles; (2) the performance outcomes of use and remember; (3) primary presentation forms, i.e., basic presentations of definitions, examples, and practice cases; and (4) secondary presentation forms such as "help" displays, elaboration, analogies, and advance organizers. Some of the rules and procedures tying these elements together are summarized and illustrated. The application of CDT is then traced from its roots in programmed instruction and CAI, through traditional forms of education, to its potential for intelligent CAI modeling of tutoring strategies. Twenty references are listed. (MES)

Computers and Instructional Design:

Component Display Theory in Transition

Brent G. Wilson

Dept. of Leadership and Educational Policy Studies
Instructional Technology
Northern Illinois University
DeKalb, Illinois 60115c

March 1987

Computers and Instructional Design: Component Display Theory in Transition

The field of instruction design (ID) has grown up around computers, programmed instruction, and other forms of "automated" or self-instruction. Most instructional theorists have tried their hand at prescribing or developing computer-based systems (e.g., Gagne, Wager, & Rojas, 1981; Merrill, Schneider, & Fletcher, 1980; Scandura, 1986; Tennyson, 1984). This is because computers provide a highly-controlled environment where manipulation of instructional variables is easily accomplished. The potential for control has led many researchers to suggest that computer-aided instructional (CAI) systems can serve as an "ID laboratory," an environment for testing and validating instructional strategies.

In many ways, CAI serves as a valid microcosm of instructional worlds. All of Gagne's nine events are needed in CAI, just as they are in traditional instructional settings. Principles of learning are just as validly applied to CAI settings as they are to traditional instruction. Presumably, the same laws of nature and instruction are at work in CAI as in traditional instruction. Although some may argue that crucial differences between the environments limit the external validity of CAI research, the fact remains that historically, a healthy interaction has existed between CAI models and instructional design theories of a more generic nature.

In this paper, we examine the relationship between instructional design theory and CAI models. We follow a "case study" sort of method, focusing on component display theory (CDT) as our working example (see Merrill, 1983 for a complete statement of the theory). We intend to show how CDT can be adapted for use with traditional instruction, with automated forms of instruction, and will continue to evolve as CAI becomes more flexible through "intelligent" enhancements.

Building Instructional Theory

In a past edition of the Handbook of Research on Teaching, Snow (1973) talked about theory development in education. An early stage of theorizing is to develop a set of categories and terms for viewing and classifying events within a problem area. This is called taxonomizing, and provides the foundation for any kind of theoretical work. The theorist wants to look at the world in ways that will "cut at the joints;" that is, in ways that will eventually lead to understanding of the phenomenon in question. A later stage in theory development is to connect the categories into relationships, to help researchers explain, predict, understand, or control the phenomenon. Thus the psychologist, having defined various categories of mental disorders, can set about defining determining conditions for those disorders. The physicist can link mass and motion in ways that result in powerful predictions; the pharmacist can determine appropriate blend of drugs designed to remedy complaints.

In the domain of instruction, the problem is more like the pharmacist's than the physicist's. We are interested in developing remedies for problems. Thus the instructional theorist needs to come up with a taxonomy for describing various kinds of learning outcomes, as well as interventions, treatments, and conditions needed to arrive at those outcomes. Simon (1969) called this kind of problem a "science of the artificial" because we are interested in understanding not so much the "natural" world, but more the "artificial" or man-made world of goal-oriented problems and solutions. Instructional theorists are interested in stimulus design as well as response, in structure of interaction as well as structure of cognitive outcomes. That is because, for any instructional problem, it is the design of the intervention that is manipulable. A student's family background may be a given, native intelligence may be a given, yet the nature of the instructional interaction is more under the instructor's control. Seen in this light, instructional research is more like engineering than science. Although lacking the precision of most engineering fields, instructional design has a similar goal-oriented structure. Were it not for the dehumanizing connotation of the term, "instructional engineering" would be an appropriate label for much of what instructional designers try to do.

Component Display Theory: An Instructional Design Theory

Merrill's component display theory is a good example of a taxonomy-based theory. Based on a field of mathematics called "set theory," Merrill defined a taxonomy of content types, including facts, concepts, procedures, and principles. Facts combined concepts in arbitrary associations; concepts were basic building-block categories defined by critical attributes; procedures were sequential steps of operations performed by a person to reach a goal; principles were cause-effect or logical relations between concepts for the purpose of explaining or predicting.

Facts can only be remembered and cannot be generalized; however, the other content elements can be taught at two levels of outcome: the remember level, in which the learner recalls the definition or statement of the content's meaning, and the "use" level, in which the learner must show mastery by applying the concept, procedure, or principle to new cases. Combining the content types with the performance level results in the basic taxonomy of cognitive learning outcomes, shown in matrix form in Figure 1.

With the goals or learning outcomes defined by the performance/content matrix, Merrill's next task was to develop a language for talking about instructional presentations (the "display" in componant display theory). He differentiated between "primary" and "secondary" presentation forms. <u>Primary presentation forms</u> were the basic presentations of definitions,

LEVEL OF PERFORMANCE	FACTS	CONCEPTS	PROCEDURES	PRINCIPLES
USE	(Fact are not traditionally applied or used	-Is this film clip in the film noir style? -Which of these instances is a concept? -Look at the map below. Is the body of water a bay or a strait?	-Start up an IBM PC. -Dub a videotape. -Process this travel request form.	-Using Gagne's 9 events, evaluate this lesson. -Apply the commutative property to the following equation. -Can you tell by looking at this document what print specifications I need to fix it?
REMEMBER	-Who is the president of U.S.? -What is the value of pi? -The symbol for helium is ______?	-What distinguishes film noir? -What is the definition of a concept? -What is the difference between a bay and a strait?	-What are the steps for starting an IBM PC? -Define the procedure for dubbing a videotape. -Tell me how to process this travel request form.	-State Gagne's 9 events of instruction? -Define the commutative rule in algebra. -Describe the inputs and outputs of the print formatting process.
	Arbitrary associations between things.	Categories of things sharing attributes in common.	Sequence of steps performed to reach a goal.	Cause-effect, logical, or process relationships between 2 or more concepts.

KINDS OF CONTENT

Figure 1. Component Display Theory's performance/content matrix, a taxonomy of cognitive learning outcomes.

examples, and practice cases with feedback, shown in Figure 2. A display could present the general statement of the concept, procedure, or principle, or an instantiation of the content. Further, the display could present the content in "expository" or "telling" fashion, or ask the student to respond to a practice case ("inquisitory" mode).

In support of these primary presentation forms, secondary presentation forms included "help" displays, elaboration displays, analogies, advance organizers, "advice" displays, and many others. Merrill and colleagues worked out a comprehensive taxonomy of display types, including algorithmic and heuristic re-statements of the content definition (see Figure 3).

Learning outcomes and presentation displays were then linked together by a set of rules. Adequacy rules referred to general techniques that could be applied across content types; for example, highlight critical or important information. Consistency rules specified different combinations of displays, depending on the targeted learning outcome, borrowing Gagne's "conditions-of-learning" approach. Examples of each are given in Figure 4.

In comparison to most educational models, CDT was highly formalized, tying technically-named elements together with explicit rules and procedures. The formal nature of the theory might put off a classroom teacher, but its explicitness and precision found a more comfortable home in computer-aided instruction. The TICCIT system, a minicomputer-based CAI system developed at Brigham Young University and the University of Texas, relied heavily on CDT constructs. The system was primarily designed by Bunderson (1973) and Merrill (1974), and is presently implemented by Hazeltine Corporation of Alexandria, Virginia. The TICCIT system adhered closely to a CDT-style model. TICCIT's authoring language incorporated CDT terms and strategies; the keyboard was customized to include keys for "RULE", "EXAMPLE", "PRACTICE", "EASY", "HARD", "HELP", and other theory-based options; content experts were asked to write their lessons within the CDT model.

The sequencing of instructional components within TICCIT (and within CDT) was largely determined by learner control. In a controversial paper, Merrill (1975) suggested that instructional designers might best individualize instruction by letting the learner decide which instructional strategies are needed in a given situation. If a learner feels a need for an example, an example may be only a keypress away. Learner control of instructional components was meant to circumvent the complex problems inherent in trying to adapt instruction to individual differences, a problem which continues today.

CDT brought a measure of precision and discipline to instruction, particularly CAI and programmed instruction. CDT generated a great deal of research, mostly confirming the value of its constructs. An extensive evaluation of TICCIT was shown to

		TELLING (no overt reponse)	ASKING (overt response required)
GENERALITY LEVEL	GENERAL	Present definition, rule statement, or other representation of the content generality.	Present example, non-example, or illustrating case.
	SPECIFIC	Ask for definition, rule statement, or paraphrase of the generality.	Present new problem, ask learner to apply the generality to the problem.
		STUDENT PERFORMANCE MODE	

Figure 2. Four kinds of primary presentation forms.

PRESENTATION	EXAMPLE
Context	Story, vignette, historical background to heighten interest and meaningfulness of content
Prerequisite	Explanation of concepts used in the definition or example that the learner may not know.
Mnemonic	External aid or device to help learner remember content. Could be a picture, verbal imagery, or phrase to help recall of verbal chains.
Mathemagenic elaboration (help)	Cues that guide learner toward important content features--typographical devices, highlighting, underlying, use of space, boxes, adjunct questions, etc.
Alternative representation	Restatement of generality using diagrams, charts, formulas, or simplified vocabulary.

Figure 3. Kinds of secondary presentation forms (for a more complete discussion, see Merrill, 1983).

CONSISTENCY RULES

To teach a concept, procedure, or principle at the use level, present:

- o A definition
- o 2 or more expository examples
- o 2 or more new practice cases with feedback

To teach a learner to paraphrase the definition of a concept, procedure, or principle, present:

- o A definition
- o An example
- o A practice item requiring definition paraphrase

To teach remember a specific case verbatim, present:

- o The case
- o A practice item asking recall of the case

ADEQUACY RULES (Displays added to those specified by consistency rules)

To teach a concept, procedure, or principle at the use level, present:

- o Mathemagenic elaboration (help) with the definition
- o Prerequisite elaboration
- o An alternative representation of the definition
- o Examples with help and alternative representations available
- o New practice cases with alternative representations of the definition available, feedback with attention-focusing cues

To teach a learner to paraphrase a definition, present:

- o A definition with a mnemonic
- o An example with help or attention-focusing information
- o Give correct-answer feedback with help or attention-focusing information

To teach a learner to remember a specific case verbatim, present:

- o correct-answer feedback

Figure 4. Illustrative adequacy and consistency rules for presenting displays to achieve cognitive learning outcomes.

increase student achievement over traditional instructor-led university courses.

Before we bring CDT up to the present, we will digress to review two basic approaches to instructional design: the analytic and the holistic methods. Understanding differences between these two methods will have some bearing on our discussion of CDT and the remainder of the paper.

Analytic vs. Holistic Methods of Instructional Design

Because education is such a complex problem-solving activity, there is room for more than one approach to doing it. Joyce & Weil (1985) have documented a number of different models of teaching, reflecting a variety of philosophical positions. The two methods described in this section are actually more "paradigms" in the Kuhnian sense of the word, describing general mind-sets and assumptions concerning the way we see things and the way we do our jobs. The descriptions are simplified types of very real differences in methodology, and are not meant to caricature either approach.

The analytic method suggests the following basic procedure in designing solutions to instructional problems and goals:

1. Break down the instruction (or the instructional problem) into its parts.

2. Assemble the parts into a teaching sequence or instructional solution, proceeding from simple to complex, from sub-skill to sub-skill, until the instructional goal is obtained.

Examples of the analytic method applied to education include the ISD model, Gagne's taxonomy of learning outcomes and conditions-of-learning approach, Gagne's learning hierarchy analysis, criterion-based measurement models, and Gilbert's performance audit. Merrill's component display theory also can be seen as an example of the analytic method.

The holistic method is somewhat harder to define for this author, an observation probably attributable to the author's background and training. A holistic method seems to follows this basic procedure:

1. Simplify the work environment until you find a task the learner can become meaningfully engaged, and with work satisfaction.

2. Develop a series of work environments in stages, allowing the learner to progress until full mastery is attained.

Examples include the mentoring relationship, the apprentice/master model, the craftsman model, and Bunderson's notion of "work models" (Bunderson, Gibbons, Olsen, & Kearsley, 1981). Holistic models of evaluation and testing are other examples. Reigeluth's elaboration theory (Reigeluth, Merrill, Wilson, & Spiller, 1980) seems to be a hybrid, making use of goals and techniques from both approaches.

The key difference between the two methods is reliance on analysis as a method of developing appropriate task environments. The analytic method specifies tasks and instructional strategies based on breakdown and re-assembly of parts; once broken down, the instructional designer "understands" the task and can re-assemble the task into a proper instructional lesson. Students systematically learn the parts, sub-skills and sub-knowledge, combining them in greater performance requirements until the whole task is mastered. The holistic method, on the other hand, takes the whole task and cuts back without a full analysis. The cutting back may be based on intuition, from common sense, or from a master's own memories of having learned the material. The instructor does not try to analyze or document the full task performance; rather she develops work environments where a valuable subset of the master's skills and knowledge can be put to good use. A series of progressing environments is what constitutes the "journey" of instruction from novice to master. The holistic method is strong on synthesis rather than analysis.

Consider the example of foreign language learning. Not long ago, the fad in language learning was the "language lab," a facility equipped with tape recorders, head-phones, and individual booths. The activity of the language lab was drill & practice--hear a sound (a word, phrase, or sentence), repeat the sound; hear a sound, respond to the sound. Theorists following the analytic method hypothesized that if learners could master the fundamental parts of the language--"automatize" them if you will--that they could build their understanding incrementally until they approached mastery.

Currently, there are scores of language labs that remain under-used. The labs failed to fulfil their expected potential; students somehow did not synthesize the bulk quantities of new knowledge they were acquiring. Theorists turned their attention toward a more holistic goal termed "communicative competence." The new emphasis is on total communication, with a corresponding deemphasis on correct syntax, structure, and vocabulary. Students stand when they say "stand," they say "water" when they get a drink. They engage in goal-based dialogues with classmates and teacher. The emphasis is on communication, however the student can manage it. Details of grammar and language structure are introduced at a later stage.

The two methods described above have their own sets of advantages and risks. The analytic method can be reliable, efficient, and useful for managing large-scale training projects. At the same time, because the analytic method builds solutions based on a breakdown of a problem, there is a tendency to focus on trivial but well-understood aspects of the problem. Chronically neglected aspects of "analyzed" instruction include attitudes, self-concept, creativity, higher-order problem solving and cognitive strategies. Similarly, at its best the holistic method can result in rich and satisfying experiences, leaving an enduring impression on the learner. Or, holistic instruction can be wasteful, misdirected, shallow, and inefficient (see Wilson, 1987). Understanding the relative strengths of the two methods can help the instructional designer who wants to be sensitive to a full range of methodologies and outcomes.

Display Assumption of CDT

From the outset of CDT's development, Merrill acknowledged an important assumption underlying the theory:

> Content can be broken down into discrete chunks or displays of instruction, and these displays can be classified and combined into suitable instructional presentations and strategies.

This assumption, virtually a restatement of the analytic method, posed no threatening constraints, and did not detract from the theory's usefulness. Indeed, the display assumption was ideally suited to basic forms of self-instruction. Teachers have traditionally been wary of instructional-design approaches, yet core ideas of component display theory have been successfully taught to classroom teachers and trainers. Subject experts are often enthusiastic about CDT because it gives them a shared vocabulary with instructional designers and a structure for approaching content analysis. Over the years the popularity of CDT among instructional designers has increased, largely because of its appealing use of content types and instructional-strategy "templates." The display assumption seems not to have hurt the theory's application to traditional instructional forms.

Merrill originally developed CDT at a time when the world of CAI was based on screen displays, called "frames" after the programmed instruction term for a chunk of instruction. Frame-based CAI follows this basic approach:

1. Script/develop screens of content, practice, etc.
2. Combine those screens into sequences of instruction, using branching, loops, and other adaptive strategies.

Today, most CAI continues to be frame-based; almost all authoring systems on the market follow a frame-based approach.

The frame-based orientation to CAI is being challenged presently by a group of long-standing critics. Generative forms of CAI utilizing artificial-intelligence methods are exerting considerable influence among CAI theorists (including Merrill and Bunderson). Intelligent computer-aided instruction (ICAI) moves instruction away from a display or frame orientation, and toward a knowledge-base orientation (Kearsley, 1987). Specifically, CAI programs explicitly try to:

- o model the content needed for mastery
- o model the current content understanding of the student
- o model the strategies of an effective tutor
- o control instruction by linking the tutoring strategies with the master's and student's knowledge states.

The modeling of strategies and knowledge states is accomplished by expert systems technology: IF-THEN rules are combined to form knowledge bases, which in turn are accessed by reasoning modules using logical inferencing strategies (Wilson & Welsh, 1986).

ICAI developers have made strides in representing content, and in modeling learner states. Where they have fallen short, in the author's opinion, is in modeling the strategies of an effective tutor. Admirable work has been done by Collins and colleagues in modeling "discovery" tutorial methods (e.g., Collins & Stevens, 1983), but their methods apply best to content already familiar to the learner. Engaging in a mixed-initiative dialogue with the computer, the learner explores and analyzes the familiar content to arrive at new conclusions and insights.

Merrill's language for talking about instruction may still be a useful mechanism, even for ICAI applications. Whereas the display assumption was once thought to refer to individual screens, the presentation chunks of "example," "practice," "analogy," "help," "advice," and so on, may also be seen as strategy chunks called up by an expert system governing instructional interactions. CDT seems to offer an excellent starting point for intelligent tutoring strategies by providing a set of correspondence rules relating specific units of instructional strategy to a range of cognitive learning objectives. If so, CDT will continue to evolve and be adapted as delivery systems grow in power and flexibility.

We made the distinction above between analytic and holistic methods of instructional design. CDT clearly fits primarily within the analytic tradition. As it is applied to ICAI development projects, however, CDT may assume more features of the holistic method. Once a knowledge base of content and instructional strategies is developed (an admittedly analytic task), the computer will be able to assist in developing work environments for the learner to meaningfully engage in complex performances. Artificial intelligence technology, particularly expert systems and natural language interfaces, can do much toward implementing Bunderson's notion of progressive stages of work models leading to mastery. The work models will have an analytic foundation, but will be able to provide many of the desirable features of the holistic method of design.

Conclusion

We have traced the application of component display theory through its roots in programmed instruction and computer-aided instruction, through traditional forms of education, and finally to its seeming potential for ICAI modeling of tutoring strategies. In each case, the concepts of CDT are applied differently: in CAI, learner control is a central feature; in traditional training and education, learner control is usually constrained by media and system forces; with ICAI, the "display assumption" shifts from discrete screen displays toward the notion of small chunks of instruction, governed by a knowledge base of tutorial rules. ICAI's ability to engage in mixed-initiative dialogue can minimize some of the problems encountered by TICCIT's radical use of learner control.

In the 1970's, Gagne objected to the notion of "content analysis," arguing that a "task" level was all that was needed--content by itself wasn't really "there" (Gagne, 1974; Gagne, 1976). Ironically, CDT's content analysis features seem to strongly appeal to instructional designers and subject experts. Moreover, the content analysis features fit easily within ICAI, one of whose major goals is to represent content through explicit logical relationships. Because much of the instructional designer's task is to represent knowledge adequately, the technologies of CDT and ICAI will probably have a lot of learn from each other.

Instructional design theory and CAI theory will continue to interact and influence each other; however, as ICAI methods continue to preoccupy the attention of CAI theorists, an increasing gap will likely develop between state-of-the-art CAI theory and general ID practice. The traditional trainer/educator will not get much out of a research symposium on ICAI methods and theory. The differences between CAI and ID practice evident in the 1970's and 80's will become more apparent in the 1990's. This makes the role of theories like CDT that can span across delivery systems all the more important, because they can link knowledge gains in one area to the other.

Component display theory is not the only promising theory that spans across CAI and ID theories. As mentioned, models of Gagne, Scandura, Landa, Lepper, to mention a few, are relevant to a variety of delivery systems. We hope that as interest continues in CAI and ICAI, a continuing relationship will be developed linking general models of instructional design to media-specific applications.

References

Bunderson, C. V. (1973). The TICCIT project: Design strategy for educational innovation: Proceedings of the educational technology symposium. Institute for Computer Users in Education (ICUE) Technical Report No. 4. Provo, UT: Brigham Young University.

Bunderson, C. V., Gibbons, A. S., Olsen, J. B., & Kearsley, G. P. (1981). Work models: Beyond instructional objectives. Instructional Science, 10, 205-215.

Collins, A., & Stevens, A. L. (1983). A cognitive theory theory of inquiry teaching. In C. M. Reigeluth (Ed.), Instructional-design theories and models: An overview of their current status. Hillsdale, NJ: Erlbaum.

Gagne, R. M. (1974). Task analysis--its relation to content analysis. Educational Psychologist, 11(1), 11-18.

Gagne, R. M. (1976). The content analysis of subject-matter: A dialogue between Robert M. Gagne and M. David Merrill. Instructional Science, 5, 1-28.

Gagne, R. M., Wager, W. W., & Rojas, A. (1981, September). Planning and authoring computer-assisted instruction lessons. Educational Technology, 17-21.

Joyce, B., & Weil, M. (1985). Models of teaching (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Kearsley, G. P. (Ed.). (1987). Artificial intelligence and instruction. Reading, MA: Addison-Wesley, in press.

Merrill, M. D. (1974). Premises, propositions, and research underlying the design of a learner controlled computer assisted instruction system: A summary for the TICCIT system. Working paper No. 44, Division of Instructional Services. Provo, UT: Brigham Young University.

Merrill, M. D. (1975). Learner control: Beyond aptitude-treatment interactions. AV/Communication Review, 23, 217-226.

Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), Instructional-design theories and models: An overview of their current status. Hillsdale, NJ: Erlbaum.

Merrill, M. D., & Boutwell, R. C. (1973). Instructional development: Methodology and research. In F. N. Kerlinger (Ed.), Review of research in education, vol. 1. Itasca, IL: Peacock.

Merrill, M. D., Schneider, E. W., & Fletcher, K. A. (1980). TICCIT. Englewood Cliffs, NJ: Educational Technology

Publications.

Reigeluth, C. M., Merrill, M. D., Wilson, B. G., & Spiller, R. T. (1980). The elaboration theory of instruction: A model for sequencing and synthesizing instruction. Instructional Science, 9, 195-219.

Scandura, J. (1986, April). Intelligent rule-based instructional systems. Paper presented at the meeting of the American Educational Research Association, San Francisco.

Simon, H. A. (1969). The sciences of the artificial. Cambridge, MA: MIT Press.

Snow, R. E. (1973). Theory construction for research on teaching. In R. M. Travers (Ed.), Second handbook of research on teaching. Chicago: Rand McNally.

Tennyson, R. (1984). Artificial intelligence methods in computer-based instructional design. Journal of Instructional Development, 7(3), 17-22.

Wilson, B. G. (1987). Applying hard and soft technologies to weaknesses in traditional instruction: Possible progress and some unintended side effects. Educational Technology, in press.

Wilson, B. G., & Welsh, J. R. (1986, November). Small knowledge-based systems in education and training: something new under the sun. Educational Technology, 7-13.

Author Notes

Requests for reprints should be sent to Brent Wilson, Northern Illinois University, GA 219--LEPS, DeKalb, IL 60115.