Instructional Science 16: 19–34 (1987)

The new Component Design Theory: instructional design for courseware authoring[1]

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Abstract This paper outlines extensions of Component Display Theory to provide the type of design guidance needed for experiential computer based instructional systems. The new Component Design Theory (CDT) extends the original theory in several significant ways. Content types are extended to content structures. These content structures include experiential as well as structural representations. Primary presentation forms are extended to primary presentation functions and the display is replaced by the transaction. Various types of transactions are identified for both structural and experiential representations. Course organization, previously described as Elaboration Theory, is included as part of the new CDT. Consistency rules are extended to include: (a) goal-content representation consistency; (b) goal/content representation – transaction consistency; and (c) goal/content representation – course organization consistency. Intervention rules are included for intra-transaction guidance, inter-transaction selection and sequence (strategy), inter-content representation selection and sequence (sequence) and control (who makes the guidance, strategy and sequence decisions, the learner or the system?). Finally a set of cardinal instructional principles is identified and the sets of rules which comprise the new CDT are suggested as prescribed procedures for implementing these cardinal principles.

Introduction

Over the past decade we have described and evaluated Component Display Theory, an instructional design theory (see Merrill & Boutwell, 1973; Merrill & Tennyson, 1977; Merrill, Reigeluth & Faust, 1979; Merrill, 1983; and Merrill, 1987a). The descriptive parts of this theory consist of a performance/content matrix for classifying instructional outcomes and primary and secondary presentation forms for describing presentation displays. The prescriptive parts of this theory consist of consistency rules which suggest that learning, resulting from instruction, will be most efficient and effective if certain combinations of primary and secondary presentation forms are used to promote a given class of performance/content outcome. Further prescriptions suggest that adequate instruction, for a given performance/content class, requires the use of certain secondary presentation forms and types of relationships between primary and secondary presentation forms. The theory also promoted learner control as a mechanism for adapting to individual differences.

Because of increased computing capability and availability, and with an increased interest in "intelligent" CAI, instructional capabilities now exist which were not previously practical. However instructional design theory has not kept pace with the increased capabilities in hardware and software.

In this paper we will outline the new "Component Design Theory". This is an attempt to extend our instructional design theory (Component Display Theory), in ways that take advantage of the increased presentation and intervention capability of existing computers. The purpose of this paper is to outline instructional design theory that will promote not merely more sophisticated programing but more importantly more effective instruction.

The Tutorial as an Instructional Model

Most contemporary instructional design theory (Reigeluth, 1983) and much traditional CAI is based on the "Branching Programed Instruction Model". The instructional strategy consists of the following events: (1) Present a page of text (which may include graphics) to the student; (2) Ask a question; (3) Provide feedback on the correctness of the student's answer; if the answer is incorrect, provide remedial material (which is sometimes omitted); and (4) Repeat this cycle. This model is often called "tutorial" CAI.

Many ICAI programs are also firmly rooted in the philosophy of Socratic tutorials. The goal seems to be to duplicate Mark Hopkins on the other end of the log[2]. Figure 1 illustrates the tutorial model as it is envisioned by the Socratic method and as it is implemented by many CAI and ICAI systems. The computer program selects information from the subject matter content and presents it to the student via text/graphic frames or helps the student to see the relationships in the content via question frames (inquiry teaching) or tests the student's understanding via question frames. In a mixed initiative dialogue the student is able to direct the sequence of these presentations to some extent but the critical variable is still the

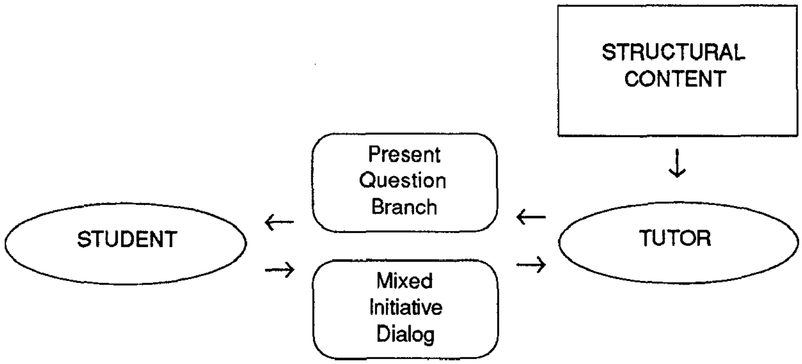

Fig. 1. The Tutorial Model

extraction of parts of the content and embedding these content fragments in presentations or questions for the student.

Figure 1 indicates that the subject matter content in this model is usually structural or static in nature as opposed to experiential. Structural content is subject matter as it is represented in a book. Principles are extracted and recorded, experiments are described or illustrated. Students may be allowed to branch from place to place but the information presented at any of these locations was previously selected and organized by the tutor (or the designer). On the other hand experiential content is responsive. It enables the student to change parameters and see the consequences. It simulates real events and procedures where input from the student results in a change in the phenomena simulated.

Is the tutorial the ideal teaching strategy? Is the tutorial the universal teaching strategy? The answer to both questions is NO. Socrates and Mark Hopkins are both highly overrated. There are many things that cannot be taught very well via tutorial dialogues. It is difficult via a tutorial to teach the procedures for operating a piece of machinery, for trouble shooting a circuit, for drawing a circuit diagram or designing a house. In fact any instructional outcome which involves learning a procedure or understanding a process is difficult to teach through only a tutorial.

Tutorials are best in two circumstances. First, to focus a student's attention while interacting with a more experiential representation of some phenomena. Second, to help a student overcome misconceptions or misunderstandings after having explored some experiential environment. However, when it comes to primary instruction, tutorial conversations are seldom sufficient.

An Experiential Instructional Model

The computer is more than a tutor. It can be not only a tutor but also the subject matter: almost any phenomenon can be simulated and the student can be given control over this simulation to explore, experiment, predict and interact with the subject matter itself. The computer can also be an expert to demonstrate the correct way to perform a procedure or to set up an experiment. The computer can be a coach or advisor to watch over the student's shoulder while he or she performs experiments, designs apparatus, solves problems. When the student is in trouble the computer can intervene to help the student with the problem, provide missing information or guide the student down a different path. Seeing the computer merely as a tutor is to limit our view. The computer can be many things simultaneously and the most effective instruction is that instruction that enables the student to interact directly with the subject matter (simulated by the computer), watch an expert perform a task (simulated by the computer), engage in a Socratic dialogue about our exploration with some subject matter, or receive coaching as he or she attempts to perform some complex cognitive task. To limit the student's interaction with the computer to only one or some subset of these possibilities fails to take advantage of the tremendous flexibility of this tool.

Figure 2 represents an experiential model of instruction. It differs from the tutorial model in that the student interacts directly with some experiential representation of subject matter. An experiential representation is one which provides some controllable microworld with which the student can manipulate and observe. An experiential representation provides a simulation of some process or procedure which enables the student to interact in such a way that the consequences of the students actions are reflected in the reactions of the system.

The most common form of transaction with such a controllable microworld is to allow the student to explore and discover the relationships involved. Often such exploration is the only transaction provided. However, exploration is only one type of transaction with an experiential representation of subject matter. According to Webster's dictionary, one definition for a transaction is, "a communicative action or activity involving two parties or two things reciprocally affecting or influencing each other". A transaction is the mutual, dynamic, real-time give and take which is possible through a computer. An instructional transaction is a dynamic interaction between the program and the student in which there is an interchange of information.

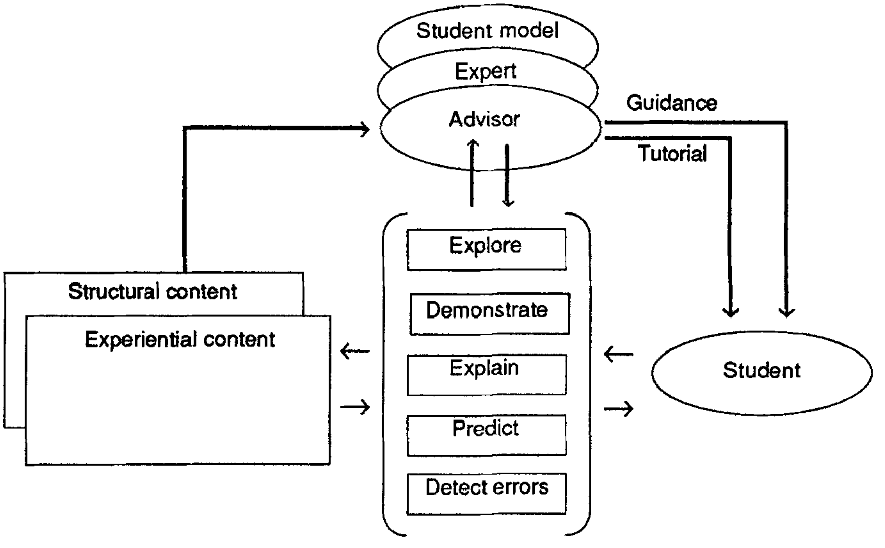

Fig. 2. Experiential/Tutorial/Advisor Model of Instruction

Figure 2 depicts an experiential model of instruction which includes a variety of transactions. While exploration is appropriate in some situations it is often not sufficient to enable the student to learn the necessary procedures or to understand all of the relationships included in the experiential simulation. Figure 2 indicates that if the experiential representation involves a process that other possible transactions may include demonstration, explanation, prediction and error detection. Transactions form the interface of the student with the experiential representation of the subject matter. The student is often able to learn more from some form of structured transactions than from open ended learner controlled exploration.

Figure 2 also adds an advisor function to the experiential model. An advisor monitors the student's exploratory behavior and provides guidance about what the student should try next in order to maximize the relationships learned. With multiple transactions included, the advisor may also serve to select or suggest what transaction should be used next and when it is advantageous to change to a new type of transaction.

Adding a student model and an expert model provides an instructional model which includes all of the components frequently mentioned as necessary for an ICAI system. The student model provides the necessary information for the advisor to guide the student's interaction with the system in an individualized way. The expert enables the system to judge the student's performance against a mastery model or enables the system to demonstrate expert performance in interacting with the system.

Finally, figure 2 combines a tutorial system with an experiential system. This would enable the advisor to direct or guide the student to engage in a tutorial conversation for the purpose of focusing attention on critical relationships in the experiential representation or for the purpose of helping the student overcome misconceptions which may have arisen from interacting with the system. In this case the advisor can also serve as a tutor engaging the student in mixed initiative conversation about his/her interactions with the experiential representation of the subject matter.

In summary, we have described the difference between a tutorial instructional model and an experiential model. In the tutorial model the tutor extracts fragments of subject matter and presents them to the learner. In the experiential model the student interacts directly with some experiential representation of the subject matter via some form of transaction interface. It was suggested that the tutorial model is most appropriate for focusing the student's attention while interacting with an experiential model. The experiential model is more appropriate for teaching the student to understand a process, as demonstrated by his/her ability to make predictions or to detect errors, or for teaching the student a procedure such as equipment operation, design or assembly. It was also suggested that an advisor which monitors the student's interactions and provides guidance is an important part of an experiential model of instruction.

The new Component Design Theory (CDT)

The original Component Display Theory (*cdt*) provided prescriptions for tutorial instruction but had little to say about experiential instruction and instructional intervention strategies. If instructional design theory is to guide the development of state-of-the-art computer based instruction then it must be appropriate not only for tutorial instruction but also for experiential instruction combined with tutorial instruction. The new Component Design Theory (*CDT*) is an attempt to extend the original *cdt* in ways that will enable it to more adequately guide the design of experiential based computer based instruction. The original *cdt* did not incorporate prescriptions for course organization (Elaboration Theory); the two sets of ideas were treated separately. The new *CDT* attempts to completely integrate principles of course organization into the main body of the theory. The original *cdt*, while advocating learner control, did not include prescriptions for on-line learner guidance concerning different transactions or different content representations. The new *CDT* attempts to include a more complete set of intervention prescriptions.

The new Component Design Theory is based on the following fundamental assumption and four cardinal principles of instruction.

Categories of learning assumption

There are different kinds of learned performance (instructional outcomes). Different instructional conditions are necessary to adequately promote a given type of learned performance (Gagné, 1965, 1985). There are different types of cognitive structure associated with different types of learned performance. There are different types of cognitive processes necessary to use each type of cognitive structure to achieve a given type of learned performance. (Note that the last two items, cognitive structure and process, extend the original Gagné assumption in ways consistent with modern cognitive science.)

The cognitive structure principle

The purpose of instruction is to promote the development of that cognitive structure which is most consistent with the desired learned performance.

The elaboration principle

The purpose of instruction is to promote incremental elaboration of the most appropriate cognitive structure to enable the student to achieve increased generality and complexity in the desired learned performance.

The learner guidance principle

The purpose of instruction is to promote that active cognitive processing which best enables the student to use the most appropriate cognitive structure in a way consistent with the desired learned performance. *Corollary 1.* The purpose of instruction is to promote the best use of the most appropriate cognitive structure by guiding the student through the most appropriate cognitive processing for that structure. This is usually accomplished by actually doing some of the processing for the student, but also by requiring the student to do more of this processing, while the instruction does less, as the instruction progresses. *Corollary 2.* The purpose of instruction is to focus attention on the relevant parts of the information provided, showing how it is related to the cognitive structure or process, but also by requiring the student to do more self-directed attention focusing, while the instruction does less, as the instruction progresses.

The practice principle

The purpose of instruction is to provide the dynamic, ongoing opportunity for monitored practice that requires a student to demonstrate the desired learned performance, or a close approximation of it, while the instruction monitors the activity and intervenes with feedback both as to result and process.

An adequate instructional design theory must include prescriptions concerning the accomplishment of each of these fundamental functions (purposes) of instruction. Figure 3 outlines the major components of the new Component Design Theory. The ovals represent descriptive components of the theory. The arrows connecting the ovals represent sets of consistency rules which are subject to empirical verification. The round corner boxes represent sets of intervention (advisor) rules for providing on-line guidance during instruction. The correspondence between the cardinal principles of instruction and the various components of the proposed theory will be explained as each component is described.

Descriptive Components and Consistency Rules of CDT

Goals

An instructional theory based on the "categories of learning" assumption must first include a taxonomy by which to classify instructional outcomes (learned performance). The old *cdt* suggested that instructional goals can be classified on two dimensions: performance and content. The performance dimension included: remember instance; remember generality; use generality; and find generality. The content dimension included: facts; concepts; procedures; and principles (processes). The new *CDT* retains this two dimensional classification system for instructional outcomes. However, *CDT* elaborates each of these categories to provide for the more detailed classification necessary to determine appropriate content structure correspondence.

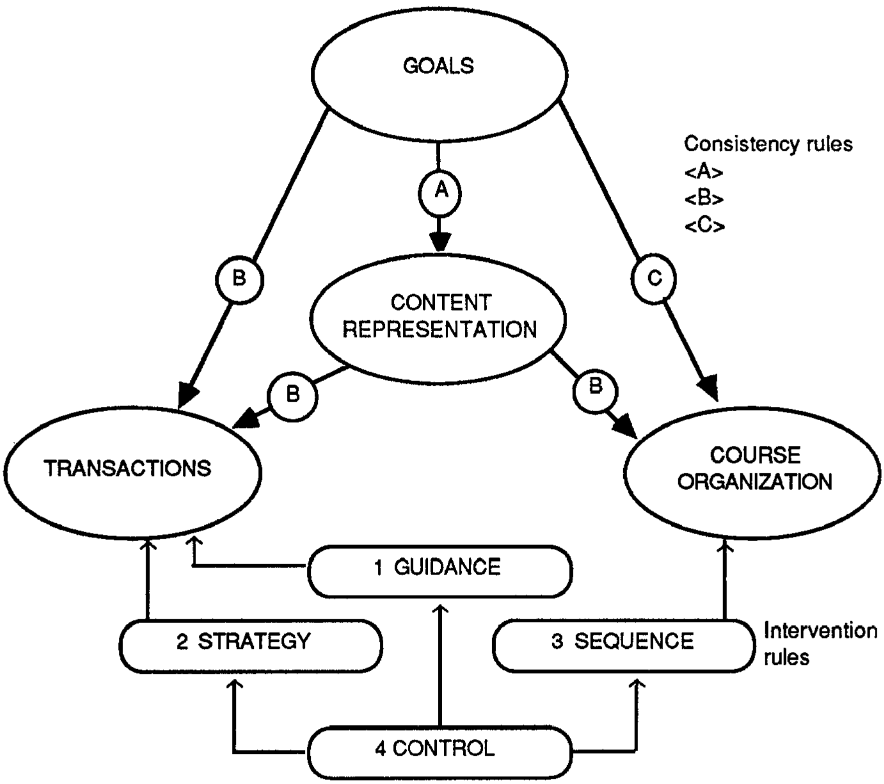

Fig. 3. Component Design Theory

Content Representation

Instructional design assumes that the deliberate manipulation of the environment promotes changes in cognitive structure and the resulting learned behavior that are more efficient or effective than similar changes which occur from interaction with a "naturally occuring" environment. Thus it is assumed that the development of a particular cognitive structure can be facilitated by instruction (the cognitive structure principle). The instructional manipulation thought to most effect the development of a particular cognitive structure is the way that the content is represented for presentation to the student. The old *cdt* identified content types (e.g. facts, concepts, procedures and principles) but little was said about the representation of this content. In the new *CDT*, content types are expanded to content structures (see Reigeluth, Merrill & Bunderson, 1978). Some of these structures include: lists; taxonomies (including parts of..., properties of..., kinds of...); decision structures; algorithms (for procedures such as calculation, assembly, operation, design); event chains (for natural processes such as life cycles); and causal chains. These content structures can be represented structurally (such as a text book might represent the subject matter) or experientially (such as a simulation might represent the subject matter). Content representations are the subject matter data base that is accessed by the student via various transactions. The content representation bubble in figure 3 represents a taxonomy of content structures and corresponding content representations.

Goal – Content Representation Consistency Rules

Learning the form of the content structure by interacting with the content representation of that structure, via an appropriate set of transactions, promotes the acquisition of the cognitive structure thought to be most appropriate for the desired learned performance (instructional outcome). The first set of prescriptions in the new *CDT* suggest that certain content structures and their associated content representations are more appropriate for some instructional outcomes whereas other content structures and their associated content representations are more appropriate for other instructional outcomes (see "A" arrow in figure 3). For example, a structural representation of a parts of taxonomy is appropriate for a remember instance outcome (e.g. "name the parts of the digestive system") whereas an experiential representation of a causal chain is more appropriate for a use principle outcome (e.g. "predict whether protein or fat is absorbed faster by the digestive system".)

Transactions

Instruction must provide not only the appropriate representation of the content to be learned but must assist the learner in using this representation (the learner guidance principle). Instruction provides this guidance via structured interactions with the representation of the subject matter content. The old *cdt* described presentations via primary presentation forms (PPFs). In *CDT*, primary presentation forms (displays) are replaced by primary presentation functions: expository generality (*EG* – present a principle, process description or definition); expository instance (*Eeg* – present an example); inquisitory instance (*Ieg* – ask the student to classify an example, do the procedure or make a prediction); and inquisitory generality (*IG* – ask the student to state the principle, describe the process or definition). Each of these functions can be instantiated via a variety of transactions. These transactions can be with structural or experiential representations of the subject matter content. Structural transactions include: conversation (*EG*, *Eeg*, *Ieg* or *IG*); explanation (*Eg* or *Eeg*); naming (*Ieg*); contrasting (*EG* or *Eeg*); and classifying (*Ieg*). Experiential transactions include: demonstration (*EG* or *Eeg*); exploration (*EG*, *Eeg*, *Ieg* or *IG*); computation (*Ieg*); assembly (*Ieg*); operation (*Ieg*); designing (*Ieg*); and predicting (*Ieg*).

Transactions also provide the opportunity for practice (the practice principle). Merely answering questions is not adequate practice. Practice often involves dynamic interaction with an experiential environment in order to solve specific problems, test specific hypotheses or design a particular artifact. Such practice is much more involved than merely question answering and requires the active monitoring via some advisor function to assist the student to adequately use the practice opportunity to improve their skill level. Intervention rules (guidance and strategy described below) provide this monitoring function during practice transactions.

Goal – Transaction Consistency

The second set of prescriptions in the new *CDT* suggest that certain transactions are more appropriate for some goal – content representation combinations while other transactions are more appropriate for other goal – content representation combinations (see "B" arrows in figure 3). For example, *naming* is an appropriate *Eeg/Ieg* transaction for a structural representation of a parts of taxonomy with a remember instance outcome (e.g. "name the parts of the digestive system") whereas *explore* is an appropriate *EG/Eeg* transaction and *predicting* is an appropriate *Ieg* transaction for an experiential representation of a causal chain with a use principle outcome (e.g. "predict whether protein or fat is absorbed faster by the digestive system").

Course Organization

To promote incremental elaboration in learned performance (the elaboration principle), subject matter content must be organized and sequenced in a way that promotes this gradual increase in skill complexity. Course organization is a representation of the ideas to be taught in the course and the relationship between these ideas. Course organization is the skeleton upon which a course is built. Seldom does a course consist of only a single type of content structure and a single representation; instead, it is usually a combination of several different structures and representations. A course usually consists of course modules each of which is composed of a particular content representation and an associated set of transactions. Course organization indicates the various paths which a student can take in moving from one module to another, as well as the control mechanisms which guide a student's progress through the course organization.

Prerequisite relationships are often used as the primary means to organize instruction (Gagné, 1985). Prerequisites, however, often fail to identify many of the important interrelationships of ideas that are important for students to learn. We have previously proposed (Reigeluth & Stein, 1983) an elaboration theory of sequence as contrasted with a cumulation theory (Gagné,1985). A cumulation theory tends to be unidimensional, based only on prerequisites. Beginning with the most primitive skills, not yet learned, each successive skill builds on another until the student finally has all of the prerequisites necessary for the terminal task. An elaboration theory tends to be multidimensional, based on a variety of content relationships. The student learns to first interact with a simple representation of the terminal task. Successive nodes in the structure add layers of complexity (i.e. alternative paths through an algorithm, or qualifications and extensions to an event or causal chain).

Figure 4 illustrates an elaborative course organization based on two types of content relationships, a "parts of..." taxonomy with event chains in each module. The center of the diagram represents a simple complete representation of a process (event chain), an example of which is *digestion*. The representation in the node is an experiential representation of an event chain consisting of a simple simulation of digestion. In an experiential representation the student would be able to adjust parameters (i.e. *the type of food ingested such as carbohydrates, sugars, protein; the time since eating, and other variables of interest*) and see the consequence of these variations (i.e. *the length of time before nutrients reach the cells of the body, the ratio of food absorbed to food particles still in the system or eliminated as waste*). The first layer of elaboration provides more detail of the process as it takes place in each part of the system. Each of the nodes at the first "layer" of elaboration is a detailed process representation as digestion occurs in each of the parts of the system, (e.g. *the mouth, stomach, small intestine and large intestine*). A third layer of elaboration provides detailed process representation of digestion as it is affected by the parts of a given part (e.g. *the saliva glands, tongue and teeth*). The number of layers of elaboration would vary depending on the goals of the instruction, the intended student audience and other factors.

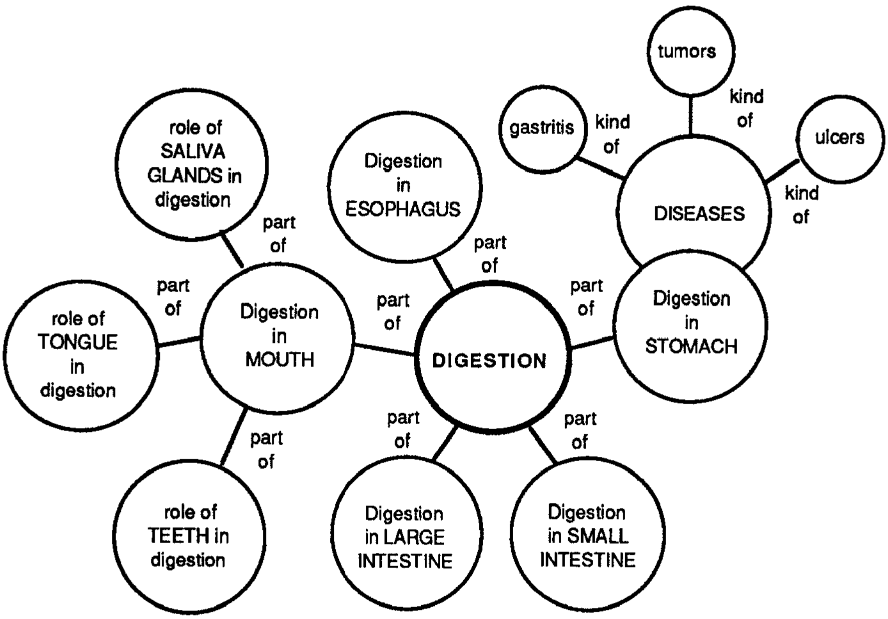

Fig. 4. Event chain content representations organized via "parts of..." elaboration.

The primary organization of a course is called the "orienting structure". It is also possible to nest other structures within this orienting structure. These supporting structures can be based on different kinds of relationships than the orienting structure. Figure 4 is an orienting structure consisting of process (event chain) representations elaborated via a "parts of..." taxonomy. It might be desirable, depending on the goals of the course, to nest a "kinds of..." taxonomy within some portion of the orienting structure. (*For example, diseases of the stomach might be a "kinds of ..." taxonomy nested within the stomach part of the orienting structure as shown in figure 4. The nodes in this structure may be structural, listing the symptoms and causes of these diseases, rather than process simulations.*)

Goal – Course Organization Consistency Rules

The third set of prescriptions in the new *CDT* suggest that certain course organizations are more appropriate for some goal – content representation combinations while other course organizations are more appropriate for other goal – content representation combinations ("C" arrows in figure 3). For example, a parts of... elaboration with structural representations in the nodes of the course organization (not shown) is an appropriate course organization for a remember instance goal (e.g. "*name the parts of the digestive system*") whereas a parts of... elaboration with experiential representations in the nodes of the course organization (figure 4) is an appropriate course organization for a use principle goal (e.g. "*predict whether protein or fat is absorbed faster by the digestive system*").

Intervention (Advisor) rules for CDT

CDT includes four classes of instructional intervention rules. These rules were not an explicit part of the original *cdt*. These rules include: (1) guidance rules; (2) strategy rules; (3) sequence rules; and (4) control rules. The guidance principle indicates that instruction should model the cognitive process for the student and then shift the execution of this process to the student. The guidance principle also indicates that the instruction should focus the student's attention on the critical information presented and show how it is related to the appropriate cognitive structure or process. Intervention rules in conjunction with the transactions provide this guidance function.

Guidance rules

The first set of instructional intervention rules are *within transaction guidance rules*. These are rules for providing guidance within a given transaction for a given type of content representation. The final implementation of these rules are often subject matter specific. Guidance rules include providing attention focusing information to the student to direct his/her attention to the critical attributes of the process being demonstrated. The guidance rules must also include information about when to withdraw this attention focusing information so as to promote increased mental processing on the part of the student.

Strategy Rules

The second set of instructional intervention rules are *transaction strategy rules*. These are rules for selecting which type of transaction should be next for a given type of content representation and when the student should shift to that next transaction type. Knowing when to shift transaction types is critical in shifting the processing from the model provided by the instruction to processing on the part of the student (Guidance principle, corollary 1). There are also control rules associated with each set of these rules which indicate whether the learner or the system makes the decision. For example, a student may be given the opportunity to explore the experiential representation of digestion. At what point is it evident that the student is learning no more from this exploration? Should the student be shifted to a more directive type of presentation? Should the student be required to demonstrate what has been learned via an inquisitory type of transaction? Strategy rules provide guidelines for establishing criterion for these adaptive decisions. Strategy rules are the principal means for providing learner guidance.

Sequence Rules

The third set of instructional intervention rules are *course sequence rules*. These are rules for selecting which node in the course structure the student should study next and when the student should shift to this new node. Sequence is the critical instructional intervention for promoting the elaboration of skill complexity (the elaboration principle). Shifting to the next level of content representation and its associated transactions is the primary mechanism for promoting elaboration. There are also control rules associated with each set of these rules which indicate whether the learner or the system makes the decision. For example, at what point has the student learned a sufficient amount about the general process of digestion so that he/she should study the process in more detail? Which detail is best to study next? Should the digestion be studied in a particular order (e.g. *is it better to study mouth to large intestine, or is it better to study the stomach first before studying the process in the mouth?*). Sequence rules would provide guidelines for establishing criteria for these adaptive decisions.

Control Rules

Control rules are a set of meta-rules which determine under what conditions the learner makes the other intervention decisions for him/herself and when the system makes the decision. The most important aspect of the guidance principle is to shift from instructional modeling to learner performance in regard to both process and attention focusing. Shifting control to the learner is the primary mechanism for assisting the student to make these transitions. A meta-objective of all instruction should be to teach the student to be a self directed learner, however, there is ample evidence that given complete learner control many students use it to their detriment rather than to their advantage. The basic learner control philosophy underlying the new *CDT* is that learners can have control as long as they make good decisions, defined as decisions that promote their acquisitions of the skills being taught in an efficient manner. When students demonstrates that they are unable to make advantageous decisions, then the learner control must be withdrawn and the system must intervene to help students make good learning decisions. The control rules, like a good parent, must continually seek to give control to a student while at the same time monitoring the student's ability to use this control. The control rules are perhaps the most challenging part of the proposed instructional design theory since so many factors and individual differences enter into the decision, who should have the control when?

Summary

Tutorial models of instruction were contrasted with experiential models of instruction. It was suggested that contemporary instructional design theory is based primarily on tutorial models. It was also observed that the availability of powerful personal computers makes possible instructional presentations that were previously not practical. It was argued that instructional design theory must be expanded to guide the development of instructional materials for these more powerful instructional delivery systems.

This paper outlined extensions of the author's original instructional design theory (Component Display Theory, *cdt*) to provide the type of design guidance needed for experiential computer based instructional systems. The new Component Design Theory (*CDT*) extends the older Component Display Theory (*cdt*) in several significant ways. Content types (facts, concepts, procedures and principles) are extended to content structures (lists, taxonomies, decisions, algorithms and event chains). Content structures are represented via structural and experiential representations. Primary presentation forms are extended to primary presentation functions and the display is replaced by the transaction. Various types of transactions are identified for both structural and experiential representations. Course organization, previously described as Elaboration Theory, is included as part of the new *CDT*. Consistency rules are extended to include (a) goal – content representation consistency, (b) goal/content representation – transaction consistency, (c) goal/content representation – course organization consistency. Intervention rules are included for intra-transaction guidance, inter-transaction selection and sequence (strategy), inter-content representation selection and sequence (sequence) and control (Who makes the guidance, strategy and sequence decisions, the learner or the system?). Finally, a set of cardinal instructional principles is identified and the sets of rules which comprise the new *CDT* are suggested as prescribed procedures for implementing these cardinal principles.

This paper is merely an outline of the types of rules to be found in the *CDT*. Several projects are under way or proposed to develop the instructional design theory outlined (Merrill, 1987b). These include: (1) Annotated Instructional Design Guides for Computer Based Instruction; (2) The USC Authoring System: Computer Aided Instructional Design; and (3) Component Design Theory: An Expert System.

Notes

1. The preparation of this paper was supported in part by funds provided by The Army Research Institute via Human Technology, Inc. The views expressed are those of the author and do not necessarily reflect the views of the sponsoring organization or Human Technology, Inc.

2. Mark Hopkins was a powerful teacher and President of William College of Massachusetts (1836-1872). It is said that the best instructional technique ever devised was Mark Hopkins on one end of a log and a student on the other.

References

Gagné, R. M. (1965).*The Conditions of Learning*. (1st Edition) New York: Holt, Rinehart & Winston.

Gagné, R. M. (1985).*The Conditions of Learning and Theory of Instruction*. (4th Edition) New York: Holt, Rinehart & Winston.

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

Merrill, M. D. & Tennyson, R. D. (1977). *Teaching Concepts: An Instructional Design Guide*. Englewood Cliffs, N.J.: Educational Technology Publications, 1977.

Merrill, M. D., Reigeluth, C. M. & Faust, G. W. (1979). The instructional quality profile: curriculum evaluation and design tool. In H. F. O'Neil, Jr. (Ed.), *Procedures for Instructional Systems Development*. New York: Academic Press.

Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), *Instructional Design Theories and Models*. Hillsdale, N.J.: Lawrence Erlbaum.

Merrill, M. D. (1987a). A Lesson Based on the Component Display Theory. In C. M. Reigeluth (Ed.), *Instructional Design Theories in Action: Lessons Illustrating Selected Theories*. Hillsdale, N.J.: Lawrence Erlbaum.

Merrill, M. D. (1987b). Applying Component Display Theory in the design of courseware. In D. Jonassen (Ed) *Instructional Designs for Microcomputer Courseware*. Hillsdale, N.J.: Laurence Erlbaum.

Reigeluth, C. M., Merrill, M. D. & Bunderson, C. V. (1978). The structure of subject matter content and its instructional design implications. *Instructional Science*, 7, 107-126.

Reigeluth, C. M. (1983). (ed.) *Instructional Design Theories and Models: an overview of their current status*. Hillsdale, N.J.: Lawrence Erlbaum.

Reigeluth, C. M. & Stein, F. S. (1983). The elaboration theory of instruction. In C. M. Reigeluth (Ed.), *Instructional Design Theories and Models*. Hillsdale, N.J.: Lawrence Erlbaum.