Chapter 7

The Descriptive Component Display Theory*

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Abstract

The Descriptive Component Display Theory describes explicitly the components of the instructional process; it dissects, identifies and summarizes learner performances; it likewise, dissects and synthesizes the subject matter content and matches content classification with learner performances. Possible presentation forms are also classified as are the modes with which these presentations can be delivered. The explicitness and scientific formality that are used are without comparison among the descriptive theories of learning and instruction. It is this exactness or precision that makes CDT especially suitable for the design of Computer-Based Training. This chapter describes what learning and instruction is about in a micro level. It describes an instructional taxonomic paradigm with a track record in technical and computer-based instructional applications as well as in less formal settings.

(DGT)

The Performance-Content Matrix

CDT holds that instructional outcomes, represented either by objectives or test items, can be classified on two dimensions: student performance (Remember-Instance, Remember-Generality, Use, and Find) and subject matter content (Fact, Concept, Procedure, and Principle). A generality (rule) is a statement of a definition, principle, or the steps in a procedure. An instance (example) is a specific illustration of an object, symbol, event, process, or procedure. Use means to apply a generality to a specific case(s). Find means to find a new generality. A fact is an association between a date and event, or a name and part. A concept is a set of objects, events, or symbols with shared common characteristics. A procedure is a set of steps for carrying out some activity. A principle is the cause-and-effect relationships in a process. CDT is appropriate only for

* This presentation of Component Display Theory is a compilation and abridgement of four original sources: Merrill, 1983; Merrill, 1987; Merrill, 1988; Twitchell, Anderton, & Parry, 1990, and some new material added for this presentation.
cognitive outcomes and does not include psychomotor or affective objectives. The classification system is summarized in Figure 7.1.

![Figure 7.1. The Performance-Content Matrix.](image)

The Gagné assumption that different outcomes require different conditions of acquisition further assumes that appropriate outcome categories can be identified, specified, and measured reliably and validly. This classification scheme is an extension of the categories originally proposed by Gagné (1965: see also Merrill, 1971). The modifications in Gagné's scheme were made to facilitate outcome classification by designers, teachers, and others interested in applied instructional design. It was also found that the content distinctions made by the performance-content matrix resulted in important differences in conditions for promoting acquisition, which were often overlooked by previous classification schemes.

In this section on the performance-content matrix we first define and illustrate each major cell of the classification matrix. The next two parts of this section describe considerations that are necessary for adequately specifying and classifying objectives and text items using the performance-content matrix.

**Performance Categories**

*Remember* is that performance requiring the student to search memory in order to reproduce or recognize some item of information previously known. *Use* is that performance that requires the student to apply some abstraction to a specific case. *Find* is that performance that requires the student to derive or invent a new abstraction.¹

For example, consider the following test items:

1. The symbol for a resistor is__________.

¹ These categories correspond roughly to Gagné's verbal information, intellectual skills, and cognitive strategy, respectively. (CMR)
2. What would happen in the circuit shown below if the load resistance were shorted?

3. Invent a simple circuit that will gradually slow a direct current motor until it stops.

The first item is at the remember level, the second is at the use level, and the third is at the find level.

Content Categories

Facts are arbitrarily associated pieces of information such as a proper name, a date, an event, the name of a place, or the symbols used to name particular objects, parts, or events. The following test items involve facts:

1. The symbol for a resistor is ____________.
2. Name the principal part of the eye.
3. Who is the president of the United States?
4. What is the value of g, the gravity constant?

Concepts are groups of objects, events, or symbols that all share some common characteristics and that are identified by the same name. Most of the words in any language identify concepts. The following test items involve concepts:

1. What characteristics distinguish Impressionist paintings from Renaissance paintings?
2. Which of the following photographs show cumulus clouds?
3. Does the analysis of the data given below require the use of a one- or two-tail statistical test?

Procedures are an ordered sequence of steps necessary for the learner to accomplish some goal, solve a particular class of problem, or produce some product. The following test items involve procedures:

1. What are the steps required to find the current in a DC circuit?
2. Use a calculator to find the mean and standard deviation of the following set of numbers.
3. Solve the following linear equations.

Principles are explanations or predictions of why things happen in the world. Principles are those cause-and-effect or correlational relationships that are used to interpret events or processes. The following test items involve principles:

1. In the following circuit explain what will happen to the intensity of the light by explaining the electron flow in the circuit.
2. Given the following case study, explain the subject's antisocial behavior in terms of reinforcement theory.
3. As concisely as possible, explain the first law of motion.2

Performance-Content Classification

According to CDT, all objectives or test items can be classified into one or more cells of the performance-content matrix. The following examples illustrate this two-dimensional classification:

Remember-fact:

1. On a topographic map, what is the symbol for a church?

2. What is the value of \( \pi \) (pi)?
   Facts have no general or abstract representation, so there is no Use-fact or Find-fact level in the matrix.

Remember-concept:

1. What are the characteristics of a conifer?

2. Define positive reinforcement.

Use-concept:

1. Is the mountain pictured in this photograph an example of a folded mountain?

2. Read the following story and identify that paragraph which best portrays the story's climax.

Find-concept:

1. Sort the rocks on this table into several different piles. Indicate the characteristics by which one of your classmates could sort them into the same piles.

2. Figure out a way to group students in a classroom that assures a range of ability, diversity in gender, and ethnicity in each group.

Remember-procedure:

1. What are the steps in balancing a checkbook?

2. Describe the steps in making a black-and-white print in the darkroom.

Use-procedure:

1. Demonstrate how to clean a clarinet.

2. Make a whip or tongue graft in a fruit tree.

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2 Concepts, Procedures, and Principles are somewhat similar to Gagné's concept (defined and concrete), rule, and higher-order rule, respectively. (CMR)
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Find-procedure:
1. Write a computer program that will index and retrieve recipes.
2. Devise a technique for randomly assigning students to experimental treatments as they enter the laboratory.

Remember-principle:
1. Explain each of the three projection techniques for making maps of the earth’s surface.
2. What happens when water evaporates? Explain in terms of molecule movement and heat.

Use-principle:
1. Read the following case study of an ecological system. In this system the rodents are increasing in number. Predict some possible hypotheses based on your knowledge of life cycles and the interdependence of species in this ecological system.
2. Below are pictures of two ocean vessels. One is floating very high in the water and the other is floating very low. Explain at least three different reasons that could account for this difference.

Find-principle:
1. Set up an experiment to assess the effect of tobacco smoke on plant growth. Report your findings.
2. Set up a demonstration that will allow you to illustrate how water gets into a well.

Specifying Objectives for the Performance-Content Matrix

There have been many prescriptions for writing objectives for instruction. Most have been modeled on Mager’s (1962) classic work and have included at least three components for an adequately stated objective: conditions, behavior, and criterion. The IDI (Instructional Development Institute) version added a specification of audience and the mnemonic specification of A B C D for the components: audience, behavior, conditions, and degree (criterion). Gagné and Briggs (1979) made another modification by suggesting that the statement should include a classification of the type of learning involved: affective, psychomotor, intellectual skills, verbal information, or cognitive strategies. The purpose of this classification was to facilitate the specification of the necessary conditions for learning.

As already indicated in a previous section of this chapter, CDT is founded on the same assumption that underlies the Gagné and Briggs prescriptions (i.e., that there are different kinds of objectives and that each type of objective requires a unique set of conditions to promote optimal acquisition of the capabilities specified by the objective). In our view, the identification of categories as part of the specification of an objective is not merely another component of form but adds the dimension of substance to the
specification. In other words, specifying the category makes it possible to indicate particular conditions, particular behavior, and particular criteria that are acceptable for a given outcome category. The addition of this dimension also changes the nature of the task of specifying objectives from one of invention to one of selection. If the taxonomy (category system) for outcomes is complete, then it can be claimed that there is only a limited set of possible objectives, and that objectives of a single type differ only in the topics that are included but do not differ significantly in either form or substance. Hence, the task for the designer is not to invent an objective but rather to select that objective that corresponds to the intended performance-content level. This addition greatly simplifies the process of specifying objectives.

Figure 7.2 summarizes the substantive conditions, behavior, and criteria that characterize each of the categories of the performance-content matrix. The categories are listed along the left-hand column. Reading across a given row, the entries in each column indicate the conditions, behavior, and criteria that are necessary to specify an objective for that performance-content category. Each component is divided into two columns, one indicating that part of the component that is fixed or necessary for the objective to characterize the specified category and the other indicating those aspects of the component that can vary and still not affect the classification of the objective. For example, for the remember-fact category, the fixed condition (column 3) is to present the symbol, object, or event that is to be named (A) and, if a set of such facts has been learned, to present the elements in random order. These two conditions are necessary for an objective to be included in the remember-fact category. However, the way that the object, event, or symbol is represented to the student can vary considerably—for example, it could be a drawing, a picture, a diagram, a model, or the actual object. The form of representation does not change the classification of the objective.

Figure 7.2 is formatted so that reading across provides a rather complete statement of a given objective. Thus, reading across the remember-fact row, an objective would be stated as follows:

Given a drawing (column 1) of an eye (A) with the parts numbered in random order (column 2), the student will be able to recall the name of each part (B) (column 3), by writing the name opposite the number corresponding to that part (column 4) with no errors and no delay (column 5), as shown by one point for each part named correctly and one point subtracted from the score for each 10 seconds over 1 minute required to complete the exercise (column 6).

Note that the author of this objective was required to fill in the topic A and to select the specific mechanisms for presenting the item and for scoring the item but that the rest of the objective was specified by the table.

**Specifying Test Items for the Performance-Content Matrix**

As with objectives, there have been many prescriptions provided for writing correctly formatted test items. Also like the prescriptions that have been provided for objectives, most of these prescriptions concentrate on the correct format for these test items rather than on the substance of the test items. It is not expedient for us to repeat these prescriptions in this chapter; rather we concentrate our discussion on those aspects of test items that affect the degree to which they measure the specified objectives.
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<td>Fixed</td>
<td>Variable 2</td>
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<td>of/for:</td>
<td>will:</td>
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<td>Drawings</td>
<td>New Examples</td>
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<td></td>
<td>Pictures</td>
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<td>Descriptions</td>
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<td></td>
<td>Diagrams</td>
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<td>Use Procedure</td>
<td>Word</td>
<td>Name</td>
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<td></td>
<td>Device</td>
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<tr>
<td>Use Principle</td>
<td>Word</td>
<td>Name</td>
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<td></td>
<td>Descriptions</td>
<td>New Problems</td>
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<td>Drawings</td>
<td>Referents from unspecified categories</td>
</tr>
<tr>
<td></td>
<td>Pictures</td>
<td></td>
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<tr>
<td></td>
<td>Descriptions</td>
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<td>Objects</td>
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<td>Find Procedure</td>
<td>Description</td>
<td>Desired Product or Event</td>
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<td>Specification</td>
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<td>Find Principle</td>
<td>Description</td>
<td>Event</td>
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<td>Observation</td>
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Figure 7.2a. Specification of objectives for P/C Matrix—use and find level.

Note: 1. Variable condition refers to representation of stimulus materials given to the student.
2. Variable behavior refers to type of performance used by the student to show capability.
3. Variable criterion refers to how a particular type of item will be scored.

An objective, when adequately specified, defines a class of acceptable test items, each of which should provide some degree of measurement for the performance-content combination represented by the objective. Hence, not only does Figure 7.2 provide a guide for specifying objectives, but it also provides a guide for the formulation of test items designed to measure those objectives. Many of the prescriptions for test items divide test items into various forms of tests, including true-false, multiple choice, matching, short answer, and essay. These item formats are independent of the performance-content levels specified by CDT. A particular category of the performance-content matrix can be assessed to some extent by any form of test item. Conversely, a given form of test item can be used to assess almost any performance level.
<table>
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<th>CRITERION</th>
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<td>Fixed</td>
<td>Variable 2</td>
</tr>
<tr>
<td>Given:</td>
<td>of/for:</td>
<td>$ will:</td>
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<tr>
<td>Remember Fact</td>
<td>Drawing</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Pictures</td>
<td>in any order</td>
</tr>
<tr>
<td></td>
<td>Diagrams</td>
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<td></td>
<td>Objects</td>
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<tr>
<td>Remember Concept</td>
<td>Word Symbol</td>
<td>Name</td>
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<td>Remember Procedure</td>
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<td>Remember Principle</td>
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Figure 7.2b. Specification of objectives for P/C Matrix—remember level.

**Input-Output Conditions**

In order to test, it is necessary to provide information and material that will be used by the student to demonstrate competence. We refer to this information and material as input for the item. The response of the student or the product resulting from this response is the second part, or output, of a test item. It is this information that will be evaluated to assess the student’s capability. The conditions column of Figure 7.2 specifies the type of input required for each type of test item and the behavior columns specify the type of output required.

**Timing Conditions**

On every test students are allowed a certain amount of time to respond to the items. The fixed criterion column in Figure 7.2 specifies these timing conditions for each performance-content category. For the remember-fact or the recall of specific instances of a concept or the recall of a fixed procedure, there should be no delay in response. For the remember-definition, procedure, or principle level, where the student is required to paraphrase or to recognize a paraphrased statement, it is necessary to allow a short delay, because searching memory for a paraphrased response does require some processing time. For the use-concept level, the student should also be allowed a short delay to allow time to study the instance and classify it. For the use-procedure and use-principle level, the performance should be untimed unless a timed response is required by the specific nature of the procedure. The find level requires considerable thinking and study and therefore should be tested by power (untimed) tests.
Prescoring Feedback

It is valuable for feedback (knowledge of correct responses) to be provided after the test is complete (meaning after the student’s performance has been scored), but any feedback that appears before the student has finished the test could have either a positive or negative influence on the student’s performance. It is desirable, therefore, to delay all feedback on the testing situation until after the test has been scored.

Prompts

Prompts consist of any information that enables the student to determine the correct response by other than the desired level of performance. There are several kinds of potential prompts in the testing situation. Deliberate hints, attention focusing, or other information is sometimes added to the content to facilitate acquisition of the information. All such prompting should be eliminated during the testing phase of the instruction. There are inadvertent prompts that sometimes are included through inappropriate format, information provided by other items on the test, and other sources of help not intended by the instructor. These sources of extraneous information should also be avoided. Finally, feedback provides a source of prompting for subsequent items. As already indicated, feedback should be delayed until after the test has been scored.

Most tests do not consist of isolated test items, but are arranged to include a set of test items often measuring the acquisition of a number of different instructional components. There are certain characteristics related to the interrelationships between these several test items that should also be considered in order to assure adequate tests.

Number of Items

Criterion-referenced tests, those intended to measure specific objectives, should be considered as a series of subtests in which the items pertaining to a single objective are considered together and separate from those items pertaining to a second objective (see Popham, 1975). Therefore, the question “How many items?” is a question about the number of items required to adequately test a single objective rather than a question about how many items should be included in the entire test designed to measure a number of different objectives. Most achievement tests err in having too few items for a single objective, therefore making measurement of the objective somewhat unreliable.

Test items for remember-facts should have one item for each fact to be learned. Test items for remember-definitions, statements of procedures, and statements of principles should require one item if the statement is to be remembered verbatim but may require two or more items if a paraphrased statement is to be recognized or recalled. Use-level items require a sample of new examples, tasks, or problems. The number of instances in this sample depends on the complexity of the phenomenon, the variance that occurs within the class of events included, and the difficulty of the classification, demonstration, or explanation. It is not possible to make adequate inference about yet-to-be-encountered situations from a single test item; reliable assessment requires demonstration of competence in a variety of specific situations. Often, one of the greatest mistakes in testing is that, because of time constraints, the more complex the situation, the fewer the items that are included for assessment. However, for reliable measurement the reverse should be the case. At the find level, the question of how many items is not as meaningful because the situation usually dictates that the students need as much information as may be required to find the solution.
Divergence and Difficulty
Whenever a test requires more than one item having the same input-output form and assessing the same objective, these items should vary from each other in such a way as to represent the variation present in the population of possible items related to this objective. If all of the items are very similar, then the increased reliability that would otherwise result from multiple-item testing of the same objective will not be gained from the repeated measurement. A similar argument can be made for item difficulty. Whenever a test requires more than one item for the same objective, these items should represent a range of difficulty from easy to hard. Presenting all easy or all hard items results in a potential distortion of the student’s performance capability.

Criterion
A fixed standard criterion such as 80% or 90% does not apply to all performance-content levels. The criterion should vary according to the category. The fixed criterion column in Figure 7.2 indicates some general criterion guidelines for each level. The figure indicates that for remember-fact there should be no errors. Either a student knows a fact or not. It makes little sense to know four of the five notes represented by the lines on the treble clef, for example. Hence, facts should be all or none, 100% correct. A similar argument holds for verbatim recall. Whenever the objective is to remember something verbatim, the criterion should be 100% correct. However, when a student is asked to paraphrase, we introduce a chance for misinterpretation even when the student remembers the definition, procedure, or principle being assessed. It may be that what is unknown is one of the words used in the paraphrase rather than the desired information itself. Because of this possibility, we should allow for some margin of error. The guide specifies this as “few errors” and would be implemented by a criterion of something like 90%. At the use level, the margin for ambiguity increases considerably. Even experts may make mistakes in some situations. The criterion should allow for this margin of error. Perhaps an 80% criterion is more appropriate. It is sometimes desirable to have a split criterion at the use level, at which the student is expected to get 95% or 100% of the easy items correct but is given considerably more room for error on the more difficult items—for example, 60% or 75%. At the find level, the number of errors seems like an inappropriate criterion because the student is discovering or inventing new information. Figure 7.2 suggests that a better criterion is some demonstration that the new knowledge works. For concepts, the definition is adequate if associates can use the new category to classify yet new instances. The procedure works if it produces the desired product or outcome. The principle is appropriate if it explains the phenomenon or allows one to make predictions about similar situations.

Primary Presentation Forms (PPF)
CDT assumes that all instructional presentations are comprised of a series of discrete displays or presentations. A presentation can be described as a sequence of such presentation forms together with the interrelationships among such forms. Four Primary Presentation Forms can be described by two dimensions: content mode (generality or instance) and presentation mode (expository or inquisitory). Expository means to present, tell, or show; inquisitory means to question, ask, or require practice. The symbols in the figure
are shorthand for expository generality (EG); expository instance (Eg); inquisitory generality (IG), and inquisitory instance (leg). The Primary Presentation Forms are summarized in Figure 7.3.

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<table>
<thead>
<tr>
<th>CONTENT MODE</th>
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<th>IG</th>
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</thead>
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<td>&quot;Rule&quot;</td>
<td>&quot;Recall&quot;</td>
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<tr>
<td>&quot;Example&quot;</td>
<td>Eg</td>
<td>Leg</td>
</tr>
<tr>
<td>&quot;Practice&quot;</td>
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</table>

Figure 7.3. The Primary Presentation Forms (PPF).
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**Generalities and Instances**

All cognitive subject matter can be represented on two dimensions. The first dimension is the specificity of subject matter. All cognitive subject matter can be represented at either a general level or a particular level. A basic component of subject matter is the concept, defined as a set of objects or events. This set of objects is described by a definition. A definition is a general statement that refers to all of the objects or events in a given class. In a parallel way, a statement of a procedure is a list of the steps involved. These steps are general in that they can be applied in a wide variety of specific situations. In a parallel way, a statement of a principle represents the general law that applies to the many specific situations to which that general law is applicable. These general statements of definition, procedure, and principle are called generalities.

Whereas a concept, procedure, and principle can be described by a generality, they may also be identified by the specific case. For a concept, a specific object or event that is defined by the concept class can be used to identify the concept. Also a specific execution of the procedure or a specific phenomenon described by the principle constitutes the specific case. These specific cases are called instances. Therefore, a given conceptual subject matter can take the form of either a generality or an instance. Facts are distinguished by having no generality. A fact is always a specific case.

**Expository and Inquisitory Presentations**

The other dimension of presentation deals with the response expectation for the student. A generality or an instance can be presented in an expository way, which entails merely telling, illustrating, or showing the student; or it can be presented in an inquisitory fashion, in which the student is expected to respond by completing the statement or applying a given generality to a specific case. In previous papers (Ellis & Wulfeck, 1978; Merrill et al., 1977), the words tell and question were used as a more vernacular description of this dimension.

3 The little "eg" is the abbreviation for example.
It is argued that all cognitive subject matter can be presented using a series of primary presentation forms and that any existing presentation can be segmented into these primary presentation-form components. By substituting symbols, a number of familiar instructional strategies can be described by merely writing a formula for the strategy. For example, \textit{EG1, EG2, EG3,...} would represent an expository presentation consisting of one generality after another; a presentation that consisted of \textit{EG1, Eeg1, EG2, Eeg2,...} would represent an expository presentation in which generalities were followed by illustrations; a presentation that consisted of \textit{Eeg1, Eeg2, Eeg3} followed by an \textit{IG} would represent some type of discovery strategy in which series of instances were presented and the student was expected to respond by finding the generality.

**Primary Presentation Form Content Consistency**

Different kinds of content require different manifestations of the four primary presentation forms. To be consistent the primary presentation form must contain the information necessary to present the content. Figure 7.4 summarizes the fundamental elements which should be present in the PPFs for each type of content. The bold words represent alternative labels by which the PPFs specific to a particular content are called.

For facts, the word \textit{pairs} indicates that facts consist of two parts: \textit{A} and \textit{B}. \textit{A} is a specific object, symbol, or event; \textit{B} is a name for this object, symbol, or event. These paired relationships are presented to the student. A given pair may also include a location for \textit{A} which the student must also learn. \textit{Name} indicates that given \textit{A} the student can supply the name; or given \textit{B} the student can locate or indicate \textit{A}.

For concepts, a definition presentation consists of providing the name of the concept, an indication of the superordinate class to which the concept belongs, and a list of the attributes and the values that the concepts assume, which distinguishes this class from coordinate classes. A definition takes the form: \textit{A [name] is a [superordinate class] which has [value on attribute 1, value on attribute 2, ... value on attribute n]}. An example presentation consists of specific objects, symbols, or events or their representation which illustrates the attribute values of the definition. It is important that values on all critical attributes are perceivable in the example given. For name practice the student is given a specific object, event, or symbol which was previously used in the Eeg presentation, and asked to remember or recall its name, or given the name, the student is asked to identify the specific object, event, or symbol to which the name refers. For classify practice the student is given a new specific object, event, or symbol, which was not previously used in Eeg, and asked to identify or recall its name, or given the name, the student is asked to select the new specific object, event, or symbol to which the name refers. At the find level, \textit{explore categories} indicates that the student is given new objects, events, or symbols, and asked to sort them in various ways in an attempt to invent a new classification scheme. No previous presentation is involved at the find level. \textit{Invent definition} indicates that after determining a suitable category, the student will formalize a definition for the new category.

For procedures, an \textit{activity} presentation consists of providing a goal and name for the procedure together with an indication of the steps, conditions, loops, and sequence involved in the execution of these steps. Activities often take the form of a flowchart. A \textit{demonstration} presentation consists of a specific device (entity) and the tools necessary to do the procedure. The procedure is then performed for the student. \textit{Demonstrate} practice consists of giving the student the goal, the entity, and the tools, and asking the student to
<table>
<thead>
<tr>
<th>P/C classification</th>
<th>Presentation</th>
<th>Practice</th>
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</thead>
<tbody>
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<td>If the instructional objective is classified as...</td>
<td>Then the EG required for a consistent presentation has...</td>
<td>Then the EG required for a consistent presentation has...</td>
</tr>
<tr>
<td>FACT</td>
<td>no generality</td>
<td>Pairs(^4)</td>
</tr>
<tr>
<td>CONCEPT</td>
<td>Definition • name • superordinate • attribute list • attribute values</td>
<td>Example</td>
</tr>
<tr>
<td></td>
<td>State Definition • name • paraphrase • definition? for FIND level Invent(^7) definition • new definition?</td>
<td></td>
</tr>
<tr>
<td>PROCEDURE</td>
<td>Activity(^8) • goal - name • steps, conditions, loops • sequence</td>
<td>Demonstration • goal - name • entity, tools • execution</td>
</tr>
<tr>
<td></td>
<td>State Steps • goal - name • paraphrase • activity? for FIND level Invent procedure • new activity?</td>
<td></td>
</tr>
<tr>
<td>PRINCIPLE</td>
<td>Proposition • name • events • concepts • relationships</td>
<td>Explanation • name • situation • execution</td>
</tr>
<tr>
<td></td>
<td>State Relationship • name • paraphrase • proposition? for FIND level Discover(^9) principle • new proposition?</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7.4. PPF specifications for different content types.\(^{10}\)

---

\(^4\) Pairs is a new term not in the original CDT papers.

\(^5\) Name is a new term not in the original CDT papers.

\(^6\) Explore is a new term not in the original CDT papers.

\(^7\) Invent is a new term not in the original CDT papers.

\(^8\) Activity is called “process” in the original CDT papers.

\(^9\) Discover is a new term not in the original CDT papers.

\(^10\) This table is a significantly revised version of the original.
execute the procedure. Two levels of practice are possible: the first requires the student to execute the procedure with the same entity and/or tools as in the definition; the second requires the student to execute a new entity and/or new tools. State steps practice consists of giving the student the goal and procedure name and having them recall or recognize a representation of the activity, usually in some paraphrased form. At the find level, explore procedures indicates that the student is given a goal and an entity and asked to find either the activity and/or tools that will enable one to reach the goal. Invent procedure indicates that after finding a suitable tool or activity the student will formally state or diagram this activity.

For principles a proposition presentation consists of providing the name for the process involved together with an indication of the concepts and events involved in this process. The proposition may also be stated as a formal law or principle. An explanation presentation consists of the name, a specific situation where the principle applies, and an execution of the events involved in the process to which the principle applies. Explain practice consists of giving the student the name or the principle, a specific situation, and asking the student to explain how the principle explains the process demonstrated by the situation. Predict practice consists of giving the student the name of the principle, a specific situation, and asking the student to predict what will happen next under a set of conditions, or what conditions caused a particular event to occur. Two levels of explain or predict practice are possible: the first requires the student to explain or predict using the same situation used in the presentation; the second requires the student to explain or predict in a new situation. State relationship practice consists of giving the student the principle name and having him or her recall or recognize a statement of the principle, usually in some paraphrased form. At the find level, explore problems indicates that the student is given one or more situations and asked to find an explanation for the events observed. Discover principle indicates that after finding a suitable solution the student provides a formal statement of the principle(s) involved.

Expository Presentations

Expository is often equated with a static page of information. Expository presentations are often called "page turning" instruction. Much of CAI seems to be based on the programmed instruction branching model of instruction illustrated in Figure 7.5. The instruction that results consists of the following events: (1) Present a page of text (which may include graphics). (2) Ask a question. (3) If the student's answer is correct, provide "you are correct" feedback; if the student's response is incorrect, provide "you are incorrect" feedback plus remedial material (which is sometimes omitted). (4) Repeat this cycle.

The branching programmed instruction model is a very limited concept of the instructional interaction. This model does not make use of the unique capabilities of the computer. The model promotes passive student interaction—the "pour it in and check to see if it stuck" theory. The model lends itself to the imitation of the textbook with "Press the Space Bar Please" substituted for "Please Turn the Page." At least with a real textbook the student can skip a few pages or scan for what is important. With computer-based programmed instruction it is often impossible to skip a page or to even know how many pages are included (Merrill, 1985).
Perhaps we are trapped by our metaphor. The term frame is often seen as synonymous with page. The CRT screen is seen as the page of a book. Hence, we limit our thinking to putting a book on the screen and branching to different pages depending on the student's response. Perhaps we should change our metaphor. Rather than the frame as the basic building block of CAI, we should use an instructional transaction. According to Webster's unabridged dictionary, one definition for a transaction is "a communicative action or activity involving two parties or two things reciprocally affecting or influencing each other." Frame is a passive concept whereas transaction is an active concept. It is the mutual, dynamic, real-time give-and-take which is possible through a computer, and which is not possible through a book, that should characterize computer-based instruction. An instructional transaction is a dynamic interaction between the program and the student in which there is an interchange of information.

Can there be an expository transaction? Is the word expository also a passive word like the word frame? According to Webster, exposition includes: "a setting forth of the meaning or purpose; an expounding of the sense or intent; an interpretation. The art of presenting a subject matter in detail...." There is nothing inherent in the meaning of the word exposition that would indicate that there can be no student interaction. It is our position that there can and should be expository transactions rather than merely expository frames in effective CAI.

One of the primary functions of instruction is to promote and guide active mental processing on the part of the student. The amount learned and retained is a function of the relevant cognitive processing done by the student when learning the information. Passive frames do little to promote such mental activity. In the next few paragraphs we will present some examples of Expository presentations, including EG and Egs, which involve transactions that require considerable processing by the student rather than passive frames. While there are many more types of transactions that would fit within our definition of expository transactions, we have selected a few representatives that show a range of possibilities. These might be characterized as conversational programming, interactive demonstrations, and controllable microworlds.
Conversational Programming

Poetic Meter

Figures 7.6, 7.7, and 7.8 illustrate expository frames from a pseudo lesson on poetic meter developed by the author to show some of the inappropriate techniques often used for CAI. The following paragraph describes the interaction:

The text shown in Figure 7.6 is presented to the student.

After reading the text the student presses the RETURN key.

![Types of Poetic Meter]

Figure 7.6. Inadequate Poetic Meter—frame 1.

The text shown below the "Press RETURN to continue" message is displayed line by line. As the bottom of the screen is reached the text scrolls up causing the top lines of the previous display (Figure 7.6) to disappear off the top of the screen.

 ordinary prose. You will learn to recognize and name four different rhythmic patterns.

Press RETURN to continue

![Background]

Figure 7.7. Inadequate Poetic Meter—frame 2.
Chapter 7: The Descriptive Component Display Theory

Pressing the RETURN key causes the text in Figure 7.7 to scroll and the new paragraph of text shown in Figure 7.8 to appear.

BACKGROUND
A major feature of poetry that distinguishes it from ordinary prose is the arrangement of words so that the stressed syllables tend to occur at regular intervals. This regular arrangement of stress produces a rhythmic pattern. It is this rhythmic pattern that is one major factor distinguishing poetry form prose.

Press RETURN to continue

A STRESSED SYLLABLE is louder and/or higher in pitch than an unstressed syllable. RHYME in poetry results from a recurring pattern of stressed and unstressed syllables.

Press RETURN to continue.

Figure 7.8. Inadequate Poetic Meter—frame 3.

A number of violations of effective screen design make this poor CAI. These include using white letters on a black screen, filling margin to margin with text, and scrolling previous messages off the screen. However, our concern here is with the noninteractive nature of the presentation. This is a classic example of a “book on the screen.” The student reads a message then presses the RETURN key for the next message. Furthermore, the scrolling causes even the page orientation to be disturbed since the message moves to a new location on the screen every time the next message is requested. It takes only a few frames presented in this fashion to put the student into a catatonic state of inattention.

Consider a revised example of this material in Figures 7.9, 7.10, and 7.11. The following paragraph describes the interaction on these frames.11

In Figure 7.9 the questions appear one by one with a 3 second pause after the display of the first question before the next question appears. The student does not respond to questions 1 and 2 but after question 3 the cursor appears for the student to enter a response.

If the student responds with rhyme, the message shown in Figure 7.9 appears. If the student responds with rhythm or meter (or another synonym of rhythm) the message says “RHYTHM or METER is very important.” The system recognizes a number of synonyms and spelling errors in the student’s answers.

11 Based on the program “Introduction to Poetry” by M. David Merrill, published by Olympus/MicroTeacher Software Inc. These materials are similar to the published program but may have been changed to better illustrate the message of this chapter.
After a short pause of 3 seconds the following message appears on the bottom of the screen: Poetry has two main characteristics:

RHYME and RHYTHM

The "turn the page" message bar shown at the bottom of Figure 7.11 then appears for the student to continue.

POETIC METER

What makes a poem a poem?

Why is a poem different from prose?

Name one characteristic of a poem.

Rhyme is one characteristic.
Can you name another?

Figure 7.9. Poetic Meter showing use of rhetorical questions.

Figure 7.10 presents an example of poetry and an example of prose and tries to show the student the difference. The black box appears with the message "Listen to this passage:" After a short pause the poem is printed syllable by syllable. Each syllable is accompanied by a beep from the computer speaker. The stressed syllables are accompanied by a high-pitched beep and the unstressed syllables are accompanied by a low-pitched beep. The effect is a series of sounds which chant the rhythm pattern of the poem.

Listen to this passage:

By the shores of Gitche Gumee,
By the shining Big-Sea-Water,
Stood the wigwam of Nokomis,
Daughter of the Moon, Nakomis.

Now listen to this passage:

This is the age of science, of steel- of seed and the cement road. Science and steel demand the medium of prose. What need then for poetry?

What is the difference? Passage 1 has

Figure 7.10. Poetic Meter showing sound reinforced examples.
The next black box now appears with the message “Now listen to this passage.” The prose example is presented in the same manner as the poetry passage. However, the rhythm pattern of the sound is irregular in this passage rather than regular.

After the prose passage is presented, the student is asked to respond to the question appearing at the bottom of the screen. The answer to the first question is “regular (steady) meter (beat, stress, rhythm).” If the student anticipates one of the correct answers, the system displays the message “GOOD” and asks the next question. The student is then asked “Passage 2 has...” The answer is “irregular (unsteady, random) meter (beat, stress, rhythm).”

Figure 7.11 is then presented. The question at the top is presented first and a cursor appears at the end of the question for the student's answer. The correct answer is louder, emphasized, higher in pitch (and a series of equivalent responses). If the student answers “stressed” a message appears “Can you think of another word?” The word “GOOD!” appears if the student types one of the anticipated answers. If not, the message shown still appears but the word “GOOD!” does not.

The black box is displayed with the poem printed in the box and the following message “Read the following passage aloud.” After the box the student has a message to press the RETURN key when finished.

When the return key is pressed the poem is removed from the black box and the message “Did it sound like this?” appears. After a pause of 2 seconds the poem is then printed syllable by syllable, accompanied by sound as in Figure 7.10. After the poem is “chanted” the turn-the-page message bar on the bottom of the screen appears.

<table>
<thead>
<tr>
<th>What is a stressed syllable?</th>
<th>A stressed syllable is:</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOOD!</td>
<td>louder</td>
</tr>
<tr>
<td></td>
<td>emphasized</td>
</tr>
<tr>
<td></td>
<td>higher in pitch</td>
</tr>
</tbody>
</table>

Did it sound like this?

All are arch/i/tects of fate, Work/ing in these walls of time, Some with mas/sive deeds and great, Some with orn/a/ments of rhyme.

Stressed syllables are: higher in pitch often found by reading aloud

--- LAST  [RET] REPEATS  NEXT --->

4

Figure 7.11. Poetic Meter showing student activity in reading passage.

Note that Figures 7.9 through 7.11 represent expository frames. Their purpose is to present the definition of poetry as contrasted with prose. Yet, they are more interactive and involve the student much more than Figures 7.6 through 7.8, which merely present text on the screen.

In Figure 7.9 we used rhetorical questions. A rhetorical question is one used “...to emphasize a point, introduce a topic, etc., no answer being expected” (Webster). The
purpose of questions 1 and 2 is to make the student think, to involve the student in a mental dialog about the topic, to cause the student to recall what is already known related to the topic. Question 3 is still rhetorical but now we have the student provide an answer. However, we are not concerned about whether or not the answer is correct. This is not practice or a test but merely a device for involving the student in an expository dialogue about the topic. This rhetorical conversation is far more effective in helping the student learn the topic than is equivalent information presented in a passive paragraph. The computer is much more like a live teacher tutoring a single student than it is like a book. We should strive for this *conversational tutoring* in our expository presentations.

In Figure 7.10 we again present some information, but we involve the student by asking the student questions to focus attention on the relevant characteristics of the examples given. This is to engage the student and to focus attention on important aspects of the presentation rather than to provide practice or testing understanding.

In Figure 7.11 we use another rhetorical question to reemphasize the idea of stress. Then we use another form of transaction by having the student read a passage aloud. We can’t check that he or she did, but if the student did, his or her understanding of the idea of stress will be reinforced. This is also not practice but merely an activity to help show the student what is meant by stress.

Figures 7.9 through 7.11 are examples of expository transactions which involve the student in a conversational tutorial, increase the level of mental effort required for the student to interact with the material, and thus increase the probability of learning. These interactive transactions are examples of expository displays from CDT.

**Writing Skills**

Figures 7.12 through 7.14 show another example of expository presentations using a conversational tutorial. The topic is usage errors frequently made by writers of English. The topic of the lesson shown is the confusion that often occurs between its and it’s. The following paragraphs describe the interaction that occurs.\(^\text{12}\)

These frames from Writing Skills illustrate expository transactions. The technique is a conversational tutorial which involves the student in a dialogue with the teacher. These are not practice. The purpose of the response is not to find out what the student knows; this will come later in an editing exercise. The purpose of the interaction is to increase the level of mental effort on the part of the student by causing the student to interact with the material in a meaningful way that facilitates understanding. It should be apparent to the reader that when expository equals conversational-tutorial, it is far more effective than expository equals turn-the-page-please.

Figures 7.12 through 7.14 show the first few frames of a conversational tutorial on writing skills. In Figure 7.12 the student is asked to provide a free form answer explaining the difference between its and it’s. The answer processing looks for key words such as “sound alike” and “mean different.” Whatever the students answer, the feedback message in the bottom box presents the message shown.

\(^{12}\) Based on the program “Writing Skills” by Marvin Rosen, Bennie Lowery, and M. David Merrill, developed by Olympus/Micro Teacher Software Inc., and published by DesignWare/Eduware Inc., San Francisco. These materials are similar to the published program but may have been changed to better illustrate the message of this chapter.
**Writing Skills**

**Why do we confuse these two words?**

- Its
- It's

They sound alike, but they mean something different.

Figure 7.12. Writing Skills showing conversational tutorial—frame 1.

Figure 7.13 the program is looking for the words “it” and “is.” The feedback message shows what is displayed if something else is typed.

**Writing Skills**

**The word it's is a contraction of?**

- I and

No. The word it's is a contraction of it and is.

Figure 7.13. Writing Skills showing conversational tutorial—frame 2.

In Figure 7.14, an example is presented in the first black box. The student is asked to type in the response in the other two black boxes. The frame shows that the student typed “it” in the first box. The response for the second box is “cat” or “the cat.” The feedback would correct the student’s first response, replacing the word “it” with the word “its” in the first response box. The correct information would be given in the feedback box.
at the bottom of the screen. The dialogue would continue in this manner, helping the student see the difference between these two words. Other frames suggest that the student substitute the separate words "it" and "is" in the sentence. The student is allowed to actually make this substitution and then read the sentence to see if it makes sense.

![Writing Skills]

In this sentence
The cat licked its paws.
The word **its**
means that the word paws
belongs to [ ]

Figure 7.14. Writing Skills showing conversational tutorial—frame 3.

**Interactive Demonstrations**

One of the most difficult curriculum areas for junior high school students is arithmetic story problems. These problems attempt to pose real world situations and have the student apply the principles of arithmetic to these situations. However, the problems posed are often contrived in such a way that while the objects and setting may be familiar, the particular manipulations involved are not. The following figure illustrates a simple visual demonstration that allows the student to manipulate the objects in the same way as required by the problem. Hopefully, allowing the student to manipulate the situation will provide the experiential base needed to better understand the story problems.\(^\text{13}\)

Figure 7.15 may appear to be practice, and in a way it is. But the real practice for word problems is to solve them without the aid of the interactive illustration. Then what is the purpose of the interactive illustration? It is an expository presentation of a series of examples of the problem with many attention-focusing devices built into the illustration, which enable the student to experience the problem. This **experiential representation** is far more effective than merely solving the problem for the student. This illustration commands attention by active involvement of the student. It focuses attention by counters and actual changes in the representation of the physical situation. It enables the

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\(^{13}\) Based on a program "Story Problems" by Charlene West, Bennie Lowery, and M. David Merrill, developed by Olympus/Micro Teacher Educational Software Inc., San Diego. This program was not published. The display shown is similar to the Olympus/Micro Teacher program but has been changed to better illustrate the message of this chapter.
student to explore correct as well as incorrect strategies. It enables the student to get a feel for the problem so that solution algorithms presented later are more meaningful and less rote. Finally, it meets the criterion for the expository presentation of examples \(E_g\) from CDT.

**Experiential Environments**

Many have advocated the preparation of experiential environments or microworlds (Papert, 1980) which a student can explore and which enable the student to learn underlying principles from a base discipline. Logo was developed as such a microworld, where the student could explore concepts of geometry and computer programming. Others have suggested that what is needed is controllable microworlds where the student can conduct experiments and experience a simulation of a phenomenon in order to learn about the underlying principles.

Figure 7.15 shows an interactive illustration representing the candy counter. The black box contains a particular arithmetic story problem based on this setting. The student is asked to solve the problem but is given the opportunity to manipulate the objects according to the problem and thus find the answer empirically rather than by computation. The student can open either jar and place the contents on the scale one unit (ounces in this case) at a time. As the candy is placed on the scale, several counters are activated. The weight and cost counters above the jar indicate the amount (in units) and the total cost of the candy removed from the jar. The counters on the scale show the price per ounce of the combined candy on the scale, the weight of the combined candy on the scale, and the total cost of the combined candy on the scale. For example, if the student pressed the " arrow, the M&M jar would open and one ounce of candy would be placed on the scale. Above the jar the counters would read: weight = 1 oz., cost = 10¢. On the scale the counters would read: price = 10¢, weight = 1 oz. and cost = 10¢. Pressing the down arrow would open the second jar and place one ounce of candy corn on the scale. The counters would change as follows: above candy corn weight = 1 oz., cost = 7¢. On the scale price = 8.5¢, weight = 2 oz., cost = 17¢. The student can continue to add or remove candy from the scale until the conditions of the problem are satisfied. This interactive illustration can be used for a wide variety of mixture problems.

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Figure 7.15. Story Problems showing interactive illustration.
An Imaginary Science

Figure 7.16 illustrates a controllable microworld that the author and his associates developed as an experimental tool to study student hypothesis-forming behavior. The student is told that this screen represents a number of instruments which enable him to observe a special scientific phenomenon called a Xenograde System (pronounced Zenograde). Xenograde systems are imaginary and created merely for the purpose of this experimental system. Each of the meters and devices is explained to the student (see the explanation below). The student is challenged to learn enough about the system so that he or she can predict the charge (chrg) and velocity (velo) of each of the two satellites (● and ○) at some specific time in the future, measured in alphon seconds. The student can stop the system, change any of the parameters, and perform a number of other experiments in an attempt to learn about the laws that govern the action of the system. This system simulates the process of science in learning about physical systems.\\n
\[14\]

Figure 7.16. Xenograde System simulation controllable world.

Figure 7.16 shows all of the meters and devices necessary to study a Xenograde system. These devices simulate the Xenograde system in real time. The Dynascope shows a diagram of the system. The particles in the nucleus of the system (●) are called alphans and migrate one by one to the outer edge of the nucleus (called the exhale phase), then they migrate back to the center of the nucleus (called the inhale phase). The time between migrations is called an alphon second and is shown on the time scale in the lower left of the screen. The number of alphans (●) in each region at each time is shown on the scale labeled inner and outer. This scale corresponds to the time scale below. The satellites (● and ○) move toward the nucleus as they rotate until they collide, then they move back toward their original orbit. The scale to the right of the screen shows the

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\[14\] Xenograde Systems was invented by Carl Bereiter. The science was expanded by M. David Merrill. This simulation of the system was programmed by Tom Eucker.
distance of each satellite from the nucleus and the arrows show the direction of
movement. The Blips scale shows when a satellite collides with the nucleus but not which
satellite collided. When a satellite collides with the nucleus it can pick up or drop off
alphons (+). As the number of alphons increases, the velocity of the satellite increases in
its inward and outward movement. The student must figure out the laws governing the
picking up and dropping off of alphons and then use these laws to predict the distance
and velocity of a satellite at some given time in the future.

The student can control the devices by pressing the spacebar. A menu of items is
presented and the student is allowed to change the value of any component of the
system. For example, the student can change the number of alphons in the nucleus, the
distance or velocity of either satellite, the constant K, or the alphon number N. Having
made these changes, the student can observe the result on the system. The student can
also stop or start the action of the system by pressing the RETURN key. Thus, by
carefully selecting what to change, the student can test various hypotheses about the
system and thereby derive the rules by which the system works.

This experiential environment may appear to be practice. If the student is given
specific problems to solve it could be practice in hypothesis testing, experimentation, and
data gathering. However, in exploration mode the system is also an expository
presentation of a large number of examples. In a way it is just like the scale in the
interactive illustration for story problems except that the rules that govern the system are
more complex and interact with each other. It may be that exploration alone is not
sufficient to teach the student about Xenograde systems. Adequate instruction will
probably involve a series of suggested experiments that the student is directed to
perform. The simulation then becomes a laboratory where the student can perform the
designated experiment. The experiment and its execution may still be considered a
demonstration, and thus an expository presentation, even though there is a considerable
amount of control that the student can exercise over the system.

The Psychology Experimenter

A second example of an experiential environment as an expository presentation is The
Psychology Experimenter15 a program developed to accompany introductory psychology
texts. It is easy to discuss laboratory experiments and to explain what happens, but
anyone who has ever conducted an experiment with human subjects knows that the
description in the textbook has only superficial resemblance to the real activity. On the
other hand, to design and conduct an experiment from scratch is a very involved effort,
and class assignments often are inadequate to provide an adequate example of the
experimental process. Furthermore, a student is lucky to get a single experiment
prepared and has only one instance rather than a set of instances. The Psychology
Experimenter was designed to make it easy to provide experience in psychological
experimentation by providing a controllable world which enables the psychology student
to set up and conduct experiments with a minimal of effort.

The package allows the student to set up a two-group experiment in any of four areas:
serial learning, paired word learning, digit span experiments and comparative size
perception experiments. The software provides an experiment editor which enables the
student to set up an experimental condition by merely selecting parameter values for a

15 The Psychology Experimenter by M. David Merrill and Bennie R. Lowery was developed by
Olympus/MicroTeacher Educational Software Inc. and is marketed by Harcourt Brace Jovanovich,
1985.
series of variables. The computer screen then presents the stimulus materials to the subjects and automatically collects the data. A data analysis program enables the student to quickly analyze the data with a t-test. The following paragraphs show some of the displays and explain how the student sets up and conducts an experiment.

Figure 7.17 shows the experiment editor. The student-experimenter can select the number of treatments (1 or 2), the treatment types (one-by-one or free recall), the type of words (meaningful, nonsense, or user defined), the number of pairs (1–26), the number of learning trials (1–10), the order of presentation (same or random), and the exposure time for each word pair in presentation (1–10 seconds).

**PAIRED WORD EXPERIMENT**

Information (1 to 6): The paired-word experiment allows you to compare the performance of two groups of subjects (Ss) as they learn pairs of words.

[SPACE BAR] to read more

**Treatment Menu**

Experiment Name: HBJ Pair
Number of Treatments: 2

<table>
<thead>
<tr>
<th>Treatment Type:</th>
<th>Treatment 1</th>
<th>Treatment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Words:</td>
<td>One-by-one</td>
<td>One-by-one</td>
</tr>
<tr>
<td>Number of Pairs:</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Number of Trials:</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Order:</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Exposure Time:</td>
<td>2 Sec.</td>
<td>2 Sec.</td>
</tr>
</tbody>
</table>

[↓↑ ← →] to next choice
[TAB] to Response Menu

[F1] to [F2] to Word list
[ESC] to exit

Figure 7.17. The Psychology Experimenter treatment menu.

**PAIRED WORD EXPERIMENT — TREATMENT 2**

User List: Please type word pairs.
Word pairs will be in the position shown when order = same.

[↓↑] to move  [← →] to enter  [ESC] to exit

Figure 7.18. The Psychology Experimenter word editor.
Figure 7.18 shows the paired word list editor which enables the student-experimenter to enter his or her own word pairs. The computer also has its own list of meaningful or nonsense words should the student-experimenter prefer to use them.

Figure 7.19 shows the response menu where the student-experimenter can select the response mode for the experiment. The variables are response type (one-by-one or free recall), order (same or random), whether the stimulus word or response word is presented as the stimulus (S-R or R-S), and directions (computer defined or user defined).

**PAIRED WORD LEARNING**

DIRECTIONS: Two response types are available: one-by-one or free recall. For one-by-one the subject is shown one word and asked to type the other. Data is the number of words typed correctly and the time required to do so.

[SPACE BAR] to read more

*Response Menu*

Experiment Name: HBJ Pair

Response Type: One-by-one  
Order: Same order  
S-R/R-S: RS  
Directions: Computer

[0≠Æ] to next choice  
[TAB] to Response Menu  
[F1] to [F2] to Word list  
[ESC] to exit

Figure 7.19. The Psychology Experimenter response menu.

**PAIRED WORD LEARNING**

Study each pair of words. Later, given one word, you will type in the other.

retract = satisfy

Figure 7.20. The Psychology Experimenter presentation of treatment.
Figure 7.20 shows the experiment as it would be presented to the subject in one-by-one treatment mode. In this type of treatment the word pairs are presented one at a time for a given length of time. The subject must learn each word pair as it is presented.

The Psychology Experimenter may appear to fall outside the scope of Component Display Theory; however, one way to conceptualize this piece of software is as a series of examples of experiments. If the generality is the procedure for conducting an experiment, then this software provides a tool for providing a series of examples which can be explored by the student. The experiential environment provided may need additional guidance from the instructor as to what constitutes an adequate experiment and what does not, as to the correct procedure for assigning subjects to treatments, and numerous other items. Nevertheless, the computer based experimenter is a tool used to represent a series of expository examples and perhaps a device for providing practice as well. In this situation the computer program is used as part of the total instructional system rather than as a stand-alone tutorial device.

Inquisitory Presentations

The term inquisitory has frequently been interpreted to mean ‘ask a question.’ The Navy version of CDT, called the Instructional Quality Inventory (Ellis and Wulfeku, 1978), substitutes the word ask for the word inquisitory. The branching programmed instruction model illustrated in Figure 7.5 substitutes answering questions (often multiple choice or short answer) for practice. The metaphor is a text or workbook with questions at the end of the chapter.

We previously suggested that a primary function of instruction is to promote active mental processing and guide cognitive processing. A second primary function of instruction is to allow the student to engage in a task or a representation of the task which is similar to the real world performance being taught. While engaged in this interaction with the task, the student should receive feedback concerning the adequacy of performance.

This process of engaging in the task is frequently called practice. This is what was intended by the term inquisitory presentations in CDT. The operational word is do. In planning CAI practice experiences we should ask, "What will the student be required to do?" Then we should ask ourselves, "How can we allow the student to do this activity with feedback?" When planning inquisitory presentations we should strive to make the interaction as functionally similar to the task being taught as is practical.

In the following paragraphs we have presented some examples of practice that attempt to engage the student in activities that resemble the task being taught and which attempt to avoid merely asking questions. These tasks involve several different types of tasks including editing, computation, error/detection, assembly/disassembly, and hypothesis testing. All of the activities illustrated are implemented on small computers with common programming languages.

Figure 7.21 shows the experiment as it would be presented to the subject in free recall response mode. The subject is shown a screen showing the stimulus word for each pair of the words in the list. The subject must correctly type each response word next to the correct stimulus word. There is no time limit in this response mode and the response...
words can be entered in any order. The data that the program collects in free recall response mode is the number of words correct and the time required to complete the list.

<table>
<thead>
<tr>
<th>PAIRED WORD LEARNING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Look at the word.</td>
</tr>
<tr>
<td>Type the other word.</td>
</tr>
<tr>
<td>satisfy =</td>
</tr>
<tr>
<td>manual =</td>
</tr>
<tr>
<td>muscle =</td>
</tr>
<tr>
<td>nonsense =</td>
</tr>
<tr>
<td>gasoline =</td>
</tr>
</tbody>
</table>

Figure 7.21. The Psychology Experimenter subject response.

Editing

Poetic Meter

Figure 7.22 illustrates a practice transaction based on the lesson on Poetic Meter, previously described. The objective of this lesson is to teach the student to find the type of poetic meter used in a given passage of poetry. This activity is called "scanning poetry" and involves several steps. The student must identify the individual syllables in multiple syllable words, the student must identify which syllables are stressed, and the student must divide the lines of the passage into poetic feet. Having accomplished these steps it is relatively easy to recognize the type of poetic meter involved. A tool that is useful to find the stress patterns is to "chant" or read the poem aloud using different stress patterns.

In Figure 7.22 a passage of poetry is presented in the editing window. Above the editing window is a menu bar consisting of several options for the student. Each item in this command menu calls a pull down menu as shown in Figure 7.23. The student can select a choice using the keyboard or by using the spacebar and return key. For example, pressing the keys [A] [D] [Return] would select the answer dactylic. Or the user can select the answer dactylic by pressing the spacebar to move the pointer to Answer on the main menu bar. Pressing [Return] shows the pull down menu. Pressing [Spacebar] moves through the choices. Pressing [Return] again selects the choice. Pressing [Escape] returns the user to the main menu.

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16 Based on the program “Introduction to Poetry” by M. David Merrill, published by Olympus/MicroTeacher Software Inc. The interaction described here is a significant modification of the editor in the published version of the program.
SCANNING POETIC METER

<table>
<thead>
<tr>
<th>A)nswer</th>
<th>C)hint</th>
<th>E)dit</th>
<th>F)eedback</th>
</tr>
</thead>
</table>

A bird came down the walk.  
He did not know I saw.  
He bit an angleworm in halves  
And ate the fellow raw.

To divide into syllables (:)  
Moves the mark (:)  
[Spacebar] mark/remove  
[Escape] retnr to menu

Figure 7.22. Practice in scanning poetry.

SCANNING POETIC METER

<table>
<thead>
<tr>
<th>A)nswer</th>
<th>C)hint</th>
<th>E)dit</th>
<th>F)eedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>T)rochaic</td>
<td>I)ambic</td>
<td>D)actylic</td>
<td>A)napestic</td>
</tr>
<tr>
<td>T)rochaic</td>
<td>I)ambic</td>
<td>D)actylic</td>
<td>A)napestic</td>
</tr>
<tr>
<td>S)yllables</td>
<td>F)oot</td>
<td>S(T)ress</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7.23. Pull down menus for poetic meter practice.

A)nswer is a multiple choice item which enables the student to select the type of meter involved in the passage. Selecting the type of meter illustrated is usually the last thing the student does as part of the practice. After selecting the answer, the system presents a RIGHT or WRONG message (See Figure 7.24) and instructs the student to press the return key to try again or the spacebar to continue to the next passage.
<table>
<thead>
<tr>
<th>A) nswer</th>
<th>C) hant</th>
<th>E) dit</th>
<th>F) edback</th>
</tr>
</thead>
<tbody>
<tr>
<td>: A bird came down the walk. He did not know I saw. He bit an angleworm in halves And ate the fellow raw.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RIGHT!** The passage is **IAMBIC**

[Return] to try again  [Spacebar] to continue

---

Figure 7.24. RIGHT/WRONG feedback for poetic meter practice.

E)dit allows the student to engage in analysis of the passage prior to answering the question. Selecting S)yllables from the E)dit menu enables the student to move a colon (:) between each set of letters using the arrow keys to move the marker (•) and the spacebar to set or remove a marker. Selecting s(T)ress from the E)dit menu enables the student to move an underline (_____) from syllable to syllable using the arrow keys to move the marker (_____) and the spacebar to set or remove the marker. Selecting F)oot from the E)dit menu enables the student to move an up-arrow (\^) between each syllable to divide the passage into poetic feet. The [Return] key returns the student to the E)dit menu to change from S)yllables to s(T)ress to F)oot. The [Escape] key enables the user to return to the command menu. The student can modify the editing of the passage as much as he or she wants prior to choosing an answer for the passage. Figure 7.25 shows a passage after the student finished editing to determine the poetic meter involved.

C)chant allows the student to select a type of meter and have the system "chant" the passage by highlighting each syllable as the computer speaker emits a high tone for stressed syllables and a low tone for unstressed syllables. This enables the user to hear various stress patterns to see which one fits.

F)eedback enables the user to have the system check the analysis done with the editor. Selecting F)eedback causes the system to highlight in turn each editing mark (•) for dividing syllables, (_) for underlining stressed syllables, and (^) for dividing poetic feet. If the student has inserted a mark where one does not belong, the system flashes the mark and beeps the speaker. The mark is not removed. If the student has failed to insert a mark where one belongs, the computer inserts the appropriate mark and flashes it while beeping the speaker. The mark does not remain inserted.
SCANNING POETIC METER

<table>
<thead>
<tr>
<th>A)nswe</th>
<th>C)hant</th>
<th>E)dit</th>
<th>F)eedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>A bird Δ came down Δ the walk.</td>
<td>He did Δ not know Δ I saw.</td>
<td>He bit Δ an angleworm Δ in halves</td>
<td>And ate Δ the fellow Δ raw.</td>
</tr>
</tbody>
</table>

To divide into syllables (Δ)

 Moves the mark (Δ)  [Spacebar] mark/remove  [Escape] re-run to menu

Figure 7.25. An edited passage from Scanning Poetry Editor.

The poetic meter scanner enables the student to engage in the careful analysis of a poem that may be required by a teacher in a homework assignment. The commercial product also has a teacher editor which enables the teacher to enter his or her own poems for student analysis. The system has the added advantage that the student’s analysis can be checked immediately and the student allowed to redo the analysis until it is correct and the correct classification has been made. While there is a question involved, the practice enables the student to engage in much more than merely answering the question. The practice essentially helps the student determine why a given passage has a given poetic meter pattern.

Writing Skills

Figure 7.26 shows the editor from Writing Skills. It would be nice to have a writing exercise where the student uses a word processor to write a composition and the computer then analyzes the composition for errors. There are some writing assistance programs, of which Writer’s Workbench is one of the most sophisticated, that are able to detect certain writing errors in original compositions (Frase and Diel, 1986). Because Writing Skills was an attempt to develop an economical package, the authors used an editing approach to the practice. It was assumed that one of the tasks after writing a composition was to edit it and detect errors that the writer may have overlooked. In this software the student is given a number of passages and asked to detect certain classes of errors. After the passage has been edited, the system scans the passage and indicates

17 Based on the program “Writing Skills” by Marvin Rosen, Bennie Lowery, and M. David Merrill, developed by Olympus/Micro Teacher Software Inc., and published by DesignWare/Eduware Inc., San Francisco. For purposes of this chapter this transaction has been modified from the version in the published software.
where the student failed to make corrections that were necessary or where the student made corrections that should not have been made.

Figure 7.26 illustrates the editor from Writing Skills. The operation is very simple. The cursor is moved throughout the passage via the arrow keys. Moving the cursor beyond the last line or top line scrolls the passage automatically if there is more.

![PRE TEST](image)

Please correct usage errors that occur in the following paragraphs:

If your going on this hike, its necessary that you prepare properly. The conrads are taking theyre waterproof tent and theirs going to be a group demonstration to show how to set it up.

Figure 7.26. The editor from Writing Skills.

I)nternt enables the student to insert words or punctuation at the cursor. The insert mode is terminated by pressing [Return] to enter the change or [Escape] to cancel the insert. The editor is not like a word processor. The only changes allowed are those anticipated by the authors of the program to prevent the student from completely changing the word structure and thus making evaluation difficult or impossible for this simple analysis program. If the student tries to make a change that is not anticipated, an error message appears in a window that is overlayed on the screen stating: “Change not anticipated. Press [Spacebar] to proceed to the next error.”

D)elete enables the student to delete the character under the cursor.

C)hange enables the student to change the character under the cursor. Change is turned off by pressing [Escape].

E)valuate causes the system to highlight each word or punctuation mark in turn. When a correct change is encountered the cursor flashes and a message is shown in the feedback window at the bottom of the screen stating: “Correct change. [Spacebar]”

The student presses the spacebar to continue the evaluation. When an incorrect change is encountered the cursor flashes and a message is shown which states: “This was correct. You should not have changed it. [Spacebar]”

When an error is missed the cursor flashes and a message is shown which states: “You missed this error. [Spacebar]”
The system does not correct the student's errors or omissions but merely points them out as described. The system can be used in test mode which turns off the evaluation feedback to the student. After the evaluation the student is allowed to return to the editing task or to go to the lesson menu.

Writing skills has a considerable amount of editing practice included. Each disk contains a pretest which includes all of the errors taught in the disk and which does not allow the evaluation to be shown to the student. The results of the pretest are shown on a menu of the lessons together with a recommendation for which lessons the student must study (see Figure 7.27). After each lesson the student is required to edit a passage of several paragraphs containing only the type of error taught in the lesson. Feedback is provided as described above. After the student has successfully studied all of the lessons in a set, he/she is given another editing opportunity with passages containing all of the errors in each of the lessons in the set. Feedback is provided as described. After all of the lessons on a disk have been successfully studied, the student is given a posttest consisting of a number of passages containing all of the errors taught in the disk. Feedback is not provided for the posttest. If the student fails any part of the test he or she is returned to the lesson menu with the recommendation to "study" the misunderstood material.

The attempt here is to provide a practice opportunity that resembles the type of editing task the student will encounter in the real world. This is an inquisitorial transaction which enables the student to do the task being taught rather than to merely answer questions about the task.

Figure 7.27. Lesson menu for Writing Skills.
Computation

Many learning experiences involve the organization of data and computation of intermediate results as well as the final value. Too often, asking a series of questions, as in the programmed instruction or workbook model, provides too much prompting to the student and does not allow him/her to do the entire process of organizing the data.

General Statistics

General Statistics\(^{18}\) is a program designed to teach the student how to compute common statistics. Figure 7.28 illustrates how to compute a Pearson Product correlation coefficient (r). In this day of high power statistics programs, the computer can do these computations from the scores with little or no intervention from the analyst. However, the philosophy of this program is to encourage the user to experience the step by step process of setting up and performing the computation.

Figure 7.28 is based on a display from General Statistics. The display consists of a command line menu on the top line that enables the student to access a number of utilities including a glossary, an on screen calculator, a scattergram of the data, and a function to evaluate the work.

![Figure 7.28](image)

The second section shows the formula for the calculation to be performed.

The third window is the work space and for this program consists of a simplified spreadsheet. The student is required to enter column headings for intermediate values, to enter data in the appropriate columns, to compute intermediate values or enter formulas for the spreadsheet to compute intermediate values, and to compute the value of the statistic.

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\(^{18}\) Based on the program "General Statistics" by Douglas Degelman, Robert M. Hubbard, Bennie Lowery, and M. David Merrill, developed by Olympus/MicroTeacher Software Inc. Unpublished. The display shown has been modified from the original for purposes of this chapter.
using the formula. The system is an assistant into which the user can enter any appropriate data, perhaps that from a text or homework assignment. (The Olympus/Microteacher program also has a demonstration mode with data already supplied, which is not described here.) The user moves the cursor with the arrow keys. To enter a value, the student types a number in the cell using a minus (-) sign when necessary. To enter a formula instead of a value, the user presses the [=] key first and then enters the formula, consisting of variables (column-row identifiers, e.g., B2) or constants and operators. The formula appears in the black register at the bottom of the spreadsheet. The result of the formula appears in the cell of the spreadsheet. To copy a formula the user presses control [D] to fill down or control [R] to fill right. The formulas are automatically adjusted for corresponding rows and columns. To compute the spreadsheet the user presses control [=]. The spreadsheet has additional rows which the user can scroll to by pressing control [U] or [D]. Pressing the arrow key beyond the upper cell or the lower cell also causes the spreadsheet to scroll.

[G]lossary enables the user to get a definition of any technical word in the program. The glossary overlays the workspace and then is removed when the student presses [escape]. The function of the glossary is secondary to our purposes here.

![Figure 7.29. General Statistics computation spreadsheet and calculator.](image)

[C]alculator enables the user to call up a simple calculator that operates like most handheld calculators. The user enters a value, an operation, another value, the equal sign. The results appear in the register as shown in Figure 7.29. The results can be transferred directly to the spreadsheet by pressing [return]. Pressing [escape] removes the calculator without transferring the value. Pressing control [C] when the calculator is displayed clears the register.

[S]cattergram enables the user to see the data plotted on a graph. The graph overlays the workspace and is removed when the user presses [escape].

[E]valuate causes the system to check the student’s work. This is the unique part of the system that distinguishes it from an ordinary spreadsheet. The system first checks to see
if all of the necessary intermediate values have been assigned to a column for calculation. If not, the value is flashed in the formula. The student must press [spacebar] to continue the evaluation or [escape] to terminate the evaluation and fix the problem identified. The intermediate calculations are checked by either comparing the formulas with the column heads or by checking the actual values filled in by the student. Any errors are flashed but not corrected.

Assembly
In addition to an editor or a spreadsheet, the computer can also represent devices to be assembled or disassembled. Perhaps one of the most fascinating and imaginative programs is Pinball Construction Set by Bill Budge. While this is a game, the implications for instruction are significant.

Figure 7.30 shows the basic construction screen from the Macintosh version of Pinball Construction Set 19. The user can use the mouse to drag parts onto the pinball machine at the left. The parts operate like their counterparts in the real world. The user can configure any type of pinball machine imaginable. Other functions represented by the scissors and the soldering iron icons in the command menu enable the user to connect parts so they interact, and to assign points to the parts so when the ball hits them they add to the score. The user can use MacPaint to decorate the glass under the balls or the display for the scores. These paintings have no effect on the play.

![Figure 7.30. Pinball Construction Set.](image)

If Bill Budge can build a pinball construction set, then it is possible to build a circuit board construction set, a blue print construction set, etc. In fact, anything for which a plan or diagram can be drawn can be constructed. By coupling this design-assembly task

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19 Published by Electronic Arts, San Mateo, CA.
with appropriate evaluation and feedback, we have the mechanism for very creative practice which far exceeds answering questions at the end of the chapter.

Panel and Equipment Operation

Many procedural tasks involve operating a control panel consisting of switches, dials, meters, buttons, and even data entry. Another type of experiential practice consists of simulating the interaction of the learner with the panel by drawing a representation of the panel on the screen and asking the learner to press buttons, flip switches, and read dials, thus providing a partial simulation of the task to be performed in the real world. It is relatively easy for the computer to check the learner’s sequence of events and to react to the student’s responses.

Figure 7.31 shows a simulation of a multimeter and a circuit diagram. The learner must demonstrate the sequence of steps necessary in using the multimeter, and show where on the circuit to place the leads to make the reading requested. The user moves the pointer with a mouse.

![Multimeter and Circuit Diagram]

To change the setting of the meter the user points to the dial. Pressing the spacebar moves the picture of the dial step by step. To attach the leads the user points to the appropriate terminal on the multimeter and presses the spacebar (or clicks the mouse). The lead is attached as shown in Figure 7.32. Pointing to the schematic, the user shows where the lead should be attached. The user continues in this manner until the entire sequence of events necessary for using the multimeter for the requested task has been completed.

The computer program monitors this sequence of actions. Feedback can be given immediately or delayed until after the user has completed the sequence. Inappropriate actions are highlighted and an appropriate message is displayed in the message box at the bottom of the screen.

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20 This program was designed by the author.
The above demonstration uses simple graphics and involves very little intelligence on the part of the computer program. Nevertheless, it provides a procedural simulation that enables the student to practice an activity similar to the sequence of events required in the actual situation. Far more sophisticated simulations of equipment and panels, which involve artificial intelligence, are being developed. Towne (1986) has developed a program that lets the user create a wide variety of equipment by moving pictures on the screen. The resulting equipment can act like the actual equipment, providing a practice environment for operating or monitoring the operation of such equipment.

Error Detection
Another form of experiential practice involves troubleshooting or error detection. Consider the example given in Figure 7.31. The circuit could contain a defective part. Given the multimeter, which for this program would operate in simulation mode so that actual readings could be obtained from a circuit diagram, the learner could be asked to locate and replace the defective part so that the circuit operates correctly. This type of experiential activity can be quite involved but simple versions are easily implemented using standard programming languages on personal computers. One of the most sophisticated applications of error detection is the work of Bill Johnson (Johnson, 1986).

Hypothesis Testing and Prediction
When a student understands a principle, he/she should be able to make predictions in specific situations concerning the application of that principle. Consider the Xenograde Science simulation presented in Figure 7.16. The student could be given a series of experiments to perform or hypotheses to test and this system would provide very good experiential practice in prediction. For example, the student could be asked to predict the velocity and charge of a given satellite at a given point in time. The simulation can then
be used to test the accuracy of this prediction and the adequacy of the student's hypothesis.

In a similar way, the Psychology Experimenter described in Figures 7.17 through 7.18 provides a miniature psychology laboratory in which a student can be let to form hypotheses and test these hypotheses by performing experiments on classmates or other students.

A simple experiential environment can be conceived for many prediction situations. Obvious examples include physics laboratories, chemistry laboratories, mathematical simulations, and many others.

A Final Note on Primary Presentation Forms

One of the primary contributions of Component Display Theory is the identification of Primary Presentation Forms and the rules that prescribe the combinations of primary presentation forms which are most appropriate for promoting specific learning outcomes. Some instructional designers have incorrectly assumed that Expository Generalities (EGs) and Expository Instances (Eigs) mean the presentation of information without student response. They have also incorrectly assumed that Inquisitory Instances (legs) are best implemented by asking questions. Applications of these incorrect assumptions often result in computer based instruction that fails to take advantage of the interactive capabilities of the computer. The resulting instruction is often little more than workbooks on the CRT.

One of the primary functions of instruction is to promote active mental processing on the part of the student. There is ample evidence that the amount and quality of the resultant learning is a direct function of the student’s appropriate cognitive processing of relevant information. Passive presentation of text-like displays does little to promote the necessary mental activity. However, the appropriate use of rhetorical questions, attention focusing information, and experiential environments can do much to increase the necessary relevant mental processing and thus increase the level of learning. The interactive nature of the computer makes the implementation of this active involvement much easier than is often possible or practical with other instructional media.

We have attempted to show that Expository does not mean passive. We have attempted to show a variety of ways that carefully orchestrated transactions provide better instruction than passive book-like presentations. We have suggested that merely answering questions is often not sufficiently similar to the real-world tasks to be performed. Better practice is provided when the computer provides interactive experiential situations in which the learner can perform a task similar to that which will be required when the skills are applied in the real world.

Secondary Presentation Forms (SPF)

Primary Presentation Forms are the major vehicle of the instruction. Secondary Presentation Forms are information added to the Primary Presentation Forms to enhance the learning that occurs. They are used to facilitate the students' processing of information or to provide items of interest, such as contextual background. Secondary presentations, appropriately used, promote an increment in the achievement and learning efficiency of students participating in the instruction.
Expository Generality (EG) Secondary Presentation Forms

Following the presentation of a generality, the instructor may find it desirable to present additional information designed to facilitate learning, but that is secondary to the primary purpose of the presentation. If this information consists of definitions of the concept components comprising the generality, it is designated as prerequisite information (EG'p)\(^{21}\). Contextual secondary presentations (EG'c) consist of historical background such as: Who discovered the principle? Where did it come about? Why is it important? Mnemonic secondary presentations (EG'mn) consist of memory aids to assist the student in remembering the generality. Attention focusing secondary presentations (EG'h) or help consists of devices such as arrows, color, numbering, exploded drawings, graphics, or boldface type, which are designed to help the student identify critical attributes and to see how the generality applies to a specific instance. Alternative representation secondary presentations (EG'r) consist of some other way to present the generality, such as a diagram, a chart, a formula, or even in other words. Other types of secondary presentation for a generality could be identified, but the ones indicated have been found to be most relevant for instructional design.

Expository Instance (Eeg) Secondary Presentation Forms

In a like manner, all of the just-mentioned secondary presentation forms can also be associated with expository instances. In an expository instance, attention focusing secondary presentations (Eeg'h) would be information added to the content for the purpose of facilitating the student’s ability to relate the instance to the generality. Contextual secondary presentations (Eeg'c) include asides of interest, embedding the instance in a story or a vignette that has far more detail than is necessary to the generality being taught. An example of such contextual information would be the story in a word problem; the focus is teaching a mathematical principle, the story merely provides a vehicle and is of secondary importance. It is sometimes desirable to have an historical elaboration of instances. If an instance happens to be a famous scientific experiment, the instruction might present the context of that experiment: Who was involved? How did it come about? Alternative representation secondary presentations (Eeg'r) for instances occur when the same instance uses more than one format. If the format of the problem is modified, it may facilitate the students’ understanding or ability to solve the problem.

Inquisitory Instance (Ieg) Secondary Presentation Forms

The most important secondary presentation for practice is feedback (FB). When a student is asked to respond to a question and is then provided information about the nature of the response, or the correct answer to the question, this is a form of secondary presentation. Feedback may be the presentation of the correct answer (FBca), the words “you’re right” or “you’re wrong” (FBrw), or a complete reworking or expository presentation of the problem after the student has attempted it (FBh).

An inquisitory instance may also be associated with prerepsonse attention focusing information (Ieg'h). This is information presented to facilitate the student’s answering of the question. An inquisitory instance may also have contextual secondary presentations (Ieg'c). A story problem is a good example; the story is merely a vehicle to provide context in which to couch the question to which the student is expected to respond.

\(^{21}\) Shorthand abbreviations are indicated in parentheses. A secondary presentation is indicated by the addition of a prime ('') with an initial indicating the nature of the information.
Inquisitorial instances may also use alternative representations (leg’r) to provide an opportunity for a student to see a problem in several formats.

Inquisitorial Generality (IG) Secondary Presentation Forms

Inquisitorial generalities may also have secondary presentations. As with inquisitorial instances, the most important secondary elaborations are feedback (FBca, FBh, and FBu). Correct-answer feedback consists of providing the student with the correct statement of the generality and is the most frequently used secondary presentation for inquisitorial generalities. Alternate representations (IG’r) often consist of graphic or pictorial presentations of relationships. Helped generalities (IG’h) usually demonstrate the application of the generality to a specific example. These secondary presentations (IG’r and IG’h) are useful for assessing a student’s ability to recognize the same relationship in a paraphrased or different form than that used in the presentation. Contextual elaboration (IG’x) for inquisitorial generalities, like that for expository generalities, consists of historical information, prerequisite information, and information about the importance of the relationship.

Using symbol shorthand to represent an instructional strategy enables us to easily describe or specify an instructional strategy. Consider the following: EG, EG’c, EG’p... would indicate the presentation of a generality followed by some contextual information followed by some prerequisite information. A presentation that consisted of EG, EG’p, Eeg, Eeg’c, Ieg’c, legFBh... would indicate a presentation in which a generality was presented, some prerequisite information involved in the generality was defined, an example was presented that involved contextual information such as a story problem, the student was asked a practice question also involving context, and the student was given feedback regarding that practice question.22

Process Displays

Process displays are a third type of presentation form that is different from either primary or secondary. A process display consists of instructions or directions presented to the student suggesting how he or she should consciously process the information that is presented. Such directions might be things like: “Close you eyes and try to say the generality in your own words.” “Think back over the past several days and try to find an object stored in your memory that illustrates the generality.” “Try to form a picture of the generality in an odd or unusual way so as to remember it more accurately.” Any type of information directing the student how to think about or how to process the information being presented would be labeled as a process display.

Procedural Displays

Procedural displays are a fourth type of presentation form. Procedural displays are directions to the student indicating how to operate the equipment being used to present

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22 The symbolism that has been adopted is similar to that suggested by Evans et al. (1962) in an article titled “The RULEG System....” The original conceptualization was to describe various forms of programmed instruction. Although primary presentation forms were not originally derived from the RULEG idea, the description of the type of information involved in each of the primary presentation forms is similar to that suggested by the authors of RULEG. The notion has been considerably expanded and applied to a much broader context, rather than being limited to programmed instruction.
the material. Examples of procedural displays are directions like: "Turn the page now." "Turn on the audio recorder."

**Interdisplay Relationships**

In addition to material that can be added to the primary presentation forms, the relationship among these forms also affects the learning that will occur. This section deals with the relationships among primary presentation forms. Interrelationships are those ways in which one display in a set is affected by another display in the set. Interdisplay relationships include: divergent, range, matching, fading, random order, chunking, response delay, PPF isolation, and learner control.

*Divergent* means that subsequent instances are different in their variable attributes. *Range* means that there is a range of difficulty represented by the instances. *Matching* means that examples are matched to nonexamples in that the attributes they share with the superordinate concept are the same but, the relevant attributes are different. Matching also means that when procedures or principles are being taught, the student is shown inappropriate applications or activities matched to the correct way to execute the activity. *Fading* means that the amount of help provided via secondary presentation forms is gradually eliminated. *Random order* means that a set of facts is presented in a different order each time. *Chunking* means that a student is required to remember only 5 to 7 new items at one time. *Response delay* indicates a timed response and is important for facts where the student can recall the association of a fact immediately. *Criterion* is the level of performance expected and should be 100% for facts, meaning that all the facts are learned. *PPF isolation* means that the primary presentation forms are clearly identified for the student. *Learner control* means that the student can determine how many instances to study, when to receive help, and other strategy decisions.

**Divergence**

Divergence means that the critical characteristic of subsequent instances should be as different from each other as possible. This set of instances represents a sample from all of the possible instances that could be included in the concept class being taught, the set of procedures being taught, or the set of phenomena to which the principle applies. Divergence helps assure that this sampling is somewhat representative. It is often impractical to attempt to systematically represent each of the irrelevant characteristics by means of an example (see Markle and Tiemann, 1969, 1971). The divergence rule is a compromise that approximates a more systematic sampling procedure. If divergence is applied then it is probable that the sample of instances presented to the student will be representative of the population of instances that may be encountered in the real world.

**Range of Difficulty**

For almost any concept, procedure, or principle some of the instances are more easily classified, executed, or explained than others. If a student is presented all typical examples, there is a tendency to undergeneralize, and thus to fail to adequately perform when difficult instances are presented. On the other hand, if only difficult examples are used, a student may have a tendency to overgeneralize. Overgeneralization occurs when the student includes examples in the concept class that do not belong, attempts to apply the procedure to situations in which it is inappropriate, or attempts to explain situations to which the explanation does not apply. The most effective presentation is one that
includes a sample of instances representing a range of difficulty. Some easy instances should be included to which it is expected that most of the students would respond correctly, as well as some very difficult instances, to which it is expected that many of the students would be unable to respond appropriately. By giving the student experience with a wide range of difficulty levels, the probability of transfer to new situations is increased. There is some overlap between the difficulty rule and the divergence rule in that presenting a divergent set of examples often includes examples of a wide range of difficulty.

Matching

There has been considerable discussion in the educational-psychology literature concerning the role of nonexamples. Frequently this literature suggests that nonexamples should not be included in instructional materials. Matching means that the nonexample should be selected in such a way that it enhances the student's ability to discriminate among characteristics that are relevant and those that are not relevant.

Matching takes different forms for the different types of content. For a concept, matching exists when all of the irrelevant or variable characteristics of the example and the matched nonexample are as similar as possible. The critical characteristics, of course, would differ. A matched nonexample might be thought of as a potentially confusing instance to which the student might overgeneralize were it not for this discrimination training.

For a procedure, a matched nonexample would demonstrate potentially incorrect ways to execute the procedure in this situation. The student is shown the correct way and then shown typical or frequently occurring errors. The consequence of those errors is pointed out. There is some controversy as to whether or not the presentation of such wrong procedures will confuse the student. In a matched correct and incorrect execution of a procedure, it is therefore critical that the correct steps be clearly identified so the student can easily discriminate the correct execution from the incorrect execution.

For a principle, a matched nonexample takes the form of a frequent, but incorrect, explanation. Previous myths or incorrect interpretations are contrasted with the correct, or more recent, explanations of the phenomena being explained or predicted. The consequence of such incorrect predictions is pointed out to the student. The incorrect explanations that are included are those that may be potentially confusing, that may be in the common folklore, that may have been taught in the past, or for which there is some probability for the student to otherwise be confused.

A cautionary note must also be attached to the preceding recommendations for matched nonexamples. Like feedback and attention-focusing help, matching directs mental processing, which facilitates comparing and contrasting instances. If all examples are matched to nonexamples, the student may not learn to internalize this compare-and-contrast operation. Therefore it is important that external matching be eliminated as the instruction progresses and that the student be directed to perform the compare-and-contrast operation with instances previously stored in memory. (See Fading.)

Isolation

Primary and secondary presentation forms have been identified for the purpose of analyzing and describing instructional presentations. In a given presentation, the clear identification of these various presentation forms is often not made explicit to the student. The generality and its elaboration may be obvious to the instructor, who is
familiar with the subject matter. However, it is often not obvious to the students. It is typical of much instruction to include examples with generalities in such a way that it may be difficult for students, unacquainted with the subject matter, to separate the main ideas from the illustrative material. This situation is characterized as *instructional hide-and-seek* because the student must look for the key ideas that are embedded in the more elaborate textual presentation. The isolation rule indicates that the primary presentation forms should be clearly separated and identified for the student by means of some type of graphic or auditory convention.

**Fading**

Fading indicates that information added to the instruction to facilitate learning during the early stages of instruction should be gradually replaced by directions to the student to increase their own level of mental processing. Thus, helping information should be used early in instruction but decreased as the instruction progresses. Matching of examples and nonexamples facilitates learning during the early stages of a presentation but should be gradually decreased as the instruction progresses. Feedback, including help that explains why a response is correct or incorrect, is beneficial early in practice, but as the practice progresses students should be required to figure the adequacy of their response without explicit helped feedback.

**Chunking**

Learners have limitations on short term processing. It has been demonstrated that a learner can adequately process seven or fewer discrete pieces of information at a given time. When a student is required to learn a large number of terms, a large number of steps in a procedure, or a large number of events in a process, learning is facilitated if the instruction assists the learner in grouping these discrete items into mind-sized chunks, that is, chunks consisting of seven or fewer individual pieces.

**Random Order**

When learning a list of individual terms or parts, learners have a tendency to use whatever aids are available to facilitate retention of this information. When items are always presented in the same order, one of these extraneous aids is the order or position of the items. When order or position is not a relevant attribute, this may interfere with later recall of this information when the items are not in the same order as during the learning. Random order means that on subsequent presentations, the order of the items is changed according to a random pattern to eliminate such extraneous but irrelevant cues to learning.

**Sequence**

When learning a large number of steps in a procedure or events in a process, it is difficult for a learner to acquire all of these elements at one time. Chunking is necessary. When learning chunks that form a sequence, such as a procedure or process, then the order in which these chunks is presented to the learner will have an effect on learning. For testing it is appropriate that all of the items be presented at once to see if the learner has acquired the sequence of events or steps. But during acquisition, learning is often facilitated if the learner acquires the sequence for a few of the items, then adds a few more, and a few more until the whole sequence is learned.
Criterion

Criterion refers to the accuracy of a learner's responses in practice or testing. For some items, like facts, a criterion of 100% is necessary. For example, if a learner is memorizing the addition facts (2 + 2, etc.), then it is necessary that all of the facts be learned. If not, the learner will not be able to use the facts not learned in doing arithmetic. If all of the facts to be learned are not necessary, then one wonders if any of the facts are necessary.

On the other hand, when a learner is acquiring a concept or a procedure, perfect performance may be too demanding. In these situations the criterion may vary from high to low depending on the accuracy of performance demanded by a real-world use of the knowledge.

For learning concepts it is often the case that a learner can acquire the ability to classify easy instances, those which are clear instances of the concept, but may have more difficulty in correctly classifying more difficult instances, those that even the experts may have difficulty classifying. In this situation a sliding criterion may be more appropriate. A sliding criterion would require high accuracy in classifying easy instances but a lower criterion of performance for more difficult instances. A similar sliding criterion may be applied in learning a procedure. Some applications of the procedure may require near-perfect performance, while in other instances a lower criterion of accuracy is permissible.

Response Delay

How soon a learner responds in a given situation also varies with the type of learning involved. In recalling facts, a delay may mean that the learner is using some form of problem solving rather than instance recall. In this situation, adequate learning is indicated by no response delay or a very short response delay. On the other hand, when a learner is classifying an unencountered instance of a concept, or applying a procedure to a previously unencountered situation, or predicting the effect of some principle in a new instance of a process, the amount of time required for the student to apply his or her learning may be significant. In these types of situations a long response delay should be permitted or the response should be untimed, allowing the learner as much time as necessary to respond.

Learner Control

Learner control determines whether the instructional system (and hence the instructor) or the learner makes decisions about the learning. Learner control can be applied to a number of learning parameters. Whenever the learning environment allows, learners should have control of reading speed and when they are ready to go to the next presentation (pace). But other items may depend on various learner attributes and the nature of the learning material. If learners are highly motivated and familiar with material to be learned, then control of presentation form is justified. If learners are not motivated, then they may seek to hurry through the instruction by going to practice before they have learned the material, or seeking help before they have tried a problem.

Number of Items

More complex information requires more instances in order for a learner to acquire an adequate mental representation of the information to be learned. Learners with lower aptitude or unfamiliar with the material require more illustrations of a concept, procedure, or process than learners with higher aptitude or who are more familiar with
the information. Number of items refers to the number of instances necessary for a given learner to have adequate instruction available.

References


