Chapter 9

Lesson Segments Based on Component Display Theory*

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Abstract

Five lesson segments are presented which illustrate various uses of CDT in the design of instruction. Each lesson segment addresses some aspect of a lesson dealing with the microscope. However, there has been no intent to form an integrated lesson with the segments—each segment is separate and distinct. Each lesson is also accompanied by objectives and notes that clarify details of the instruction and explanations of how CDT was used in the segment.

(DGT)

Sample Lesson Segments

This chapter does not attempt to present a comprehensive lesson dealing with the microscope. In instructional design, a Training Needs Assessment would be conducted to determine the characteristics of the performance problem or need. If the need proved to be skills or knowledge-based, then other assessment tools (i.e., job analysis, etc.) would be undertaken to outline the training goals and objectives in detail. An integrated lesson would then be designed around the objectives. However here, to demonstrate the use of CDT, several independent approaches have been taken with no intent to create an integrated or comprehensive lesson. The purpose is to illustrate possible applications of CDT. Since CDT is not a method, but rather a theory, this chapter is used to illustrate a different instructional method for each lesson segment. A properly integrated lesson would not have used such a wide variety of methods and delivery systems.

* This presentation of Component Display Theory is a compilation and abridgment of four original sources: Merrill, 1983; Merrill, 1987; Merrill, 1988; Twitchell, Anderton, & Parry, 1990, and some new material added for this presentation.
Each lesson segment in this chapter is proceeded by a statement of the objective. The objective is classified on the performance/content matrix and is followed by a brief description of the method/delivery system used for the segment. Each segment is followed by end notes which clarify the application of CDT to the lesson.

Lesson Segment 1

History of the Microscope

Objective: Remember-Instance-Fact

"Students will be able to state from memory the three significant events in the history of the microscope."

Instructional Method: Flash cards

The CDT prescriptions for teaching Remember-Instance-Fact Objectives could be implemented in many ways. Fragment 1 suggests that the student drill using flash cards. One part of each association is placed on one side of the card and the associated information on the other. The student is instructed to look at the first side and recall the information on the reverse side before turning the card to check the correct answer feedback. The student is further advised to repeat the process until a criterion of no errors and immediate recall is achieved.

<table>
<thead>
<tr>
<th>SEGMENT ONE note 1</th>
</tr>
</thead>
</table>

SIGNIFICANT EVENTS in the History of the Microscope

There are several important events in the history of the microscope. You will be required to remember each of these events.

1. What was probably the first magnifying glass? note 2
   Ans: A glass globe filled with water.

2. Who probably used the first magnifying glass?
   Ans: Engravers.

3. When was this first magnifying glass used?
   Ans: About 3000 years ago.
4. When were the first solid glass lenses used?  
   Ans: About 1590.

5. Who developed the first compound microscope?  
   Ans: Zacharias Janssen.

6. When was the first compound microscope developed?  
   Ans: About 1590.

**Learning Tip**

Use the following cards for drill: note 3  
Look at the front and say the information on the back. note 4  
Shuffle the cards and try again. note 5  
Repeat until you make no mistakes and your answers are immediate. note 6

<table>
<thead>
<tr>
<th>Front</th>
<th>Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>First magnifying glass. What?</td>
<td>Glass globe filled with water.</td>
</tr>
<tr>
<td>First magnifying glass. When?</td>
<td>3000 years ago</td>
</tr>
<tr>
<td></td>
<td>Approx. 1000 BC.</td>
</tr>
<tr>
<td>First magnifying glass. Who?</td>
<td>Used by Engravers.</td>
</tr>
<tr>
<td>First solid glass lens. When?</td>
<td>Late 1200’s AD.</td>
</tr>
<tr>
<td>First compound microscope. When?</td>
<td>About 1590 AD.</td>
</tr>
</tbody>
</table>
Notes for Segment 1

Remember Instance Fact, Rule 1

Note 1: The presentation should consist of an expository instance (example—Eeg) followed by an inquisitory instance (practice—Leg) where the practice instance is the same as the example instance (Rule 1a).

NOTE: The first page of the sample lesson, which lists the six events that the student is to remember, is a set of six Eegs. The second page of the lesson, which contains the flash cards for use in student practice, is a corresponding set of the six Legs.

Note 2: Each instance should consist of an arbitrary association of a symbol-symbol, object-symbol, event-symbol, object-event, object-object, etc. (Rule 1b).

NOTE: The six facts to be memorized involved the association of dates (events) with objects or people (objects) with inventions (objects). Each of these associations is arbitrary in the sense that there is no generality which can be used to derive the association.

Note 3: Feedback for each Leg should consist of correct answer information (Rule 1d).

NOTE: The back of each flash card provides correct answer information for the student.

Note 4: Subsequent practice trials should present the set of pairs to be associated in random order (Rule 1f).

NOTE: Shuffling the flash cards provides random order.

Note 5: The entire set of associations should be learned without error (Rule 1k).

NOTE: The students are instructed to practice with the flash cards until they make no mistakes. It should be noted that when one is memorizing facts, a criterion of less than 100% is not meaningful. Either you need to know a particular association or you do not. It is like learning only 24 of the letters of the alphabet — which 2 is it unnecessary to know? If less than 100% is OK, then one wonders if it is necessary to learn any of the facts.

Note 6: In practice mode (Leg), given one item of the pair the student should be able to provide the associated item without delay (Rule 1j).

NOTE: The students are instructed to provide the answer immediately. While problem solving requires time, associations should require minimal processing time.
Lesson Segment 2

Convex Lenses

Objective: Use-Concept

"Students will be able to classify previously unencountered lenses as to whether or not they are convex lenses."

Instructional Method: Expository Workbook

The CDT prescriptions for teaching Use-Concept Objectives could be implemented in many ways, including discovery, conversational tutorial, or expository. We have selected a straightforward expository workbook method which starts by presenting a reference example followed by the definition. The definition is followed by some elaboration. Next follows a section consisting of several matched example-nonexample pairs. Each pair is accompanied by attention focusing help. The example section is followed by practice which asks the student to classify drawings of lenses as to whether or not they are convex. The practice is followed by helped feedback.

SEGMENT TWO
CONVEX LENSES note 1

INTRODUCTION

This segment will teach you to identify convex lenses. Study the reference example and the key idea, then study the examples which follow. Finally, practice classifying convex lenses by completing the study problems.

REFERENCE EXAMPLE

This drawing illustrates a convex lens.
KEY IDEA notes 2, 3

All convex lenses have two characteristics:
1. at least one side is curved out,
2. thick middle and thin edges.

Study the reference example and key idea until you are sure you understand the difference between convex and concave, then turn to the next page and study the examples.

HELPFUL INFORMATION notes 4, 5

The term convex means curved or rounded like the outside of a ball. You should be careful to distinguish it from the term concave, which also means curved or rounded, but like the inside of a ball. The following drawing shows the difference between convex and concave.

![Diagram showing convex and concave sides]

EXAMPLES note 6

This is a convex lens.

<table>
<thead>
<tr>
<th>Thin</th>
<th>Curved out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thick</td>
<td></td>
</tr>
<tr>
<td>Thin</td>
<td></td>
</tr>
</tbody>
</table>

Note:
- one side curved out
- thick in the middle
- thin at the edges

This is not a convex lens.

<table>
<thead>
<tr>
<th>Thick</th>
<th>Curved in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin</td>
<td></td>
</tr>
<tr>
<td>Thick</td>
<td></td>
</tr>
</tbody>
</table>

Note:
- both sides curved in
- thin in the middle
- thick at the edges
MORE EXAMPLES note 7

This is a convex lens.

Thin ➔ Curved out
Thick ➔
Thin ➔

This is not a convex lens.

Same Thickness
Neither side curved

Note:
- one side curved out
- thicker in the middle
- thinner at the edges
- left side is concave
- right side is convex

Note:
- neither side curved
- same thickness

Study the examples until you are sure you can identify convex lenses, then turn to the study problems and test your knowledge.

STUDY PROBLEMS notes 8, 9

Following are several practice problems that will ask you to distinguish convex lenses from other types of lenses. Read each question carefully and then write your answer in the space provided.
LEARNING TIP

These questions are like those you will be required to answer on the quiz for this segment. If you get lazy and sneak a peek at the answer section before you have written your answer, you may not be able to remember the information during the actual quiz.

Problem 1 You may recall from segment one that water-filled glass globes were the first magnifying glasses. Would they be classified as a convex lens? Explain your answer.

Yes No

Problem 2 Look at the following illustration. Circle one letter corresponding to the convex lens.

A B C D

Problem 3 Imagine a drop of water resting on a flat surface. Would it be a kind of convex lens? Explain your answer.

Yes No
Problem 4 Look at the following illustration. Circle the letter of each lens that is convex.

A B C D

Check your answers. When you are sure they are correct, turn the page for the correct answers and explanations.

ANSWERS FOR STUDY PROBLEMS

Problem 1 Yes. Water-filled globes have both characteristics of a convex lens: at least one curved surface and the middle is thicker than the edges.

Problem 2 D. Only example D has both characteristics. Example C is curved out on one side but has the same thickness at both the middle and the ends. Example B is thick in the middle and thin on the edges but it is not a lens because it is not curved. See the following illustration.
Segment 2 page 6

Problem 3 Yes. A water droplet always has a curved surface which is thicker in the middle than at the edges. See the following illustration.

![Diagram of a water droplet showing thin and thick lines with a curved out section.]

Problem 4 B & D are convex. A & C are not convex. Try to explain why each example is or is not convex.

If you missed any of the study problems, perhaps it would be wise to review the key ideas and examples before going to the next segment in this lesson.

Notes for Segment 2

Use Concept, Rule 8

Note 1: The presentation should consist of an expository generality (Definition—EG) followed by a set of expository instances (Examples—Eegs) consisting of several different examples, followed by a set of previously unencountered inquisitory instances (Classify—legs.N) consisting of several additional instances different from the instances used for Eegs (Rule 8a).

NOTE: The generality or definition of the concept convex lens is presented by the Key Idea appearing in the box. A set of examples, somewhat different from each other, are presented and labeled EXAMPLES. The STUDY PROBLEMS present yet another set of instances requiring the student to classify those which are convex lenses and those which are not.

Note 2: Each of the primary presentations should be isolated from surrounding text and related information so that the main ideas and illustrations of these ideas are easily identified by the student (Rule 8m).

NOTE: Several techniques are used to isolate the primary presentation forms in this lesson. First, labels—REFERENCE EXAMPLE, KEY IDEA, HELPFUL INFORMATION, EXAMPLES, STUDY PROBLEMS, ANSWERS FOR STUDY PROBLEMS—are used to call attention to the different sections. Second, the key idea is separated from the text by a box drawn around the definition.

Note 3: The expository generality (EG) should consist of a definition of the concept. The definition should include identification of the superordinate class, the
relevant attributes which distinguish instances of this concept from coordinate concepts within the same superordinate class, and the relationship of these attributes to one another. Each of the examples (Eegs) should be a specific object, event, or symbol from the class or a representation of a specific object, event or symbol from the class. If a representation is used it must include all of the relevant attributes as defined by EG. Each of the practice examples (Legs.N) should also be a specific object, event, or symbol from the class or a suitable representation that includes all of the relevant attributes. Further, the practice examples (Legs.N) should be different from the examples (Rule 8b, 8c, 8d).

NOTE: The superordinate concept for the definition is lens. The coordinate concepts are different kinds of lenses; hence the relevant attributes are those which distinguish one kind of lens from another, in this case the nature of the curved surface and the direction of the curve. Instances for both Eeg and leg are drawings (representations) of lenses rather than actual lenses. The lesson would be improved if the student had the opportunity to actually see and classify some actual lenses. The drawings do illustrate the critical attributes, i.e., curvature and thickness, thus enabling the student to make appropriate classifications. The down side is that the drawings exclude many of the irrelevant characteristics that would be present if actual lenses were used. Thus, classifying diagrams may be easier than classifying actual lenses. The practice items are somewhat different from the examples requiring the student to do more than merely remember specific instances.

Note 4: The definition (EG) should be elaborated by way of secondary presentation forms, which provide attention-focusing information to help the student identify the relevant attributes and to help the student recall prerequisite information (Rule 8e). The definition should also be restated or represented via some different mode such as a graphic, chart, or diagram (Rule 8g).

NOTE: The reference example serves as one form of alternative representation of the definition. The notes on the diagram indicating the thickness of the lens and the direction of curvature are attention-focusing devices to help the student identify the critical characteristics of a convex lens. The helpful information is another attempt to present the generality in a slightly different way and thus clarify the meaning for the student.

Note 5: The examples (Eegs) should also be elaborated by secondary presentation forms, which provide attention-focusing information (sometimes called prompting) linking the specific attributes of the examples to the labels for these attributes contained in the definition (Rule 8h). The amount of this helping information should be faded or gradually decreased during the later stages of the presentation (Rule 8p). Different examples should also be presented using alternative modes of representation (Rule 8i).

NOTE: Examples contain arrows and labels to call attention to the relevant attributes. The relevant attributes, or lack of relevant attributes, of a particular example or nonexample are listed below the diagram. There is little fading of this prompting during the example presentation. The lesson would be strengthened if examples without this additional information were also presented. When attention-focusing information is immediately available, students tend to rely on this information before they study the
examples long enough. This provides them the illusion of understanding when in fact they still need to put forth more mental effort. The fading of attention-focusing information promotes this increased mental effort. This lesson is weak in this respect. The divergence of representation would be better if actual lenses were used.

Note 6: Examples that are presented in Egs should be matched to potentially confusing nonexamples from coordinate concepts within the same superordinate concept. This procedure assists the student to discriminate members of the class from nonmembers (Rule 8o). This matching procedure should be used early in the presentation but faded during the later stages of the presentation (Rule 8p). Matching should not be used during practice legs (Rule 8r). Both examples and nonexamples should be presented for student classification but they should be presented one-by-one in a random order to minimize unintentional prompts (Rules 8r, 8t).

NOTE: In the example presentation each example is paired with a similar nonexample. This matching assists the student in discriminating relevant from irrelevant characteristics.

Note 7: Subsequent examples in both Egs and legs should be divergent from one another so that the student is exposed to the variety of instances that can be included in the concept class. This procedure assists the student to generalize to all members of the concept class (Rule 8i).

NOTE: There is some divergence in that several different kinds of lenses are represented. Within the limits of using only a limited number of representation forms, we have used considerable divergence in what could be classified as a convex lens.

Note 8: The practice instances (legs) should be presented using a variety of representation modes (Rule 8j). Student responses should be followed by feedback, which provides attention-focusing information which shows the student why the instance belongs to the concept class under consideration (Rule 8k). This attention focusing help should not be used prior to the student’s response, and the amount of information provided should be faded during the later stages of practice (Rule 8s). When help is not faded, students become help-dependent and do not try as hard as they might before responding because they know that not only the correct answer but also an explanation will follow.

NOTE: The Study Problems do provide some variety in the representation of the instances used. In addition to the diagrams there are descriptions of water-filled globes and drops of water. This divergence of representation would be better if there were actual lenses for the student to classify. There is some attempt to limit the amount of attention-focusing information in the feedback, but it may not provide enough unassisted practice.

Note 9: In both the example and practice stages of the instruction, the instances used should represent a range of difficulty (Rules 8q, 8t). This procedure assures exposure to the variety of instances the student is likely to encounter following the instruction.
NOTE: In practice the recognition of a drop of water as a convex lens is a more difficult example than the drawings which have been used in the example section. More complex concepts require even greater range of difficulty.

Lesson Segment 3

Focal Length

Objective: Remember-Generality-Concept
“Students will be able to define focal length.”

Instructional Method: Printed Study Sheet
In an integrated lesson, this objective would not usually be treated as an isolated lesson segment but would be integrated with a segment teaching the concept focal length or teaching the principle of magnification. This lesson fragment is included here to illustrate the CDT prescriptions for teaching a Remember-Generality objective. The CDT prescriptions for teaching Remember-Generality-Concept could be implemented in several ways. The lesson fragment included presents a reference example followed by definitions for each of the components of the definition of focal length. The student is asked to label a diagram illustrating focal length. The definition of focal length is restated and the student is asked to supply the words focal point or focal length as appropriate.

SEGMENT THREE
FOCAL LENGTH note 1

INTRODUCTION
One of the most important characteristics of a lens is its focal length. The illustrations and statements which follow define focal length.

REFERENCE EXAMPLE notes 2, 3
The drawings illustrate focal length for a convex lens.
Segment 3 page 2

DEFINITION

The **principal plane** of a lens is an imaginary slice from edge to edge through the center of the lens.

The **principal axis** of a lens is an imaginary line through the center of the lens perpendicular to the principal plane of the lens.

A light ray passing through the lens on the principal axis is not bent. Light rays that are parallel to the principal axis are bent when passing through the lens. Light rays bend toward the thicker part of the lens.

The **focal point** of a convex lens is that point on the principal axis where all the light rays passing through the lens parallel to the principal axis converge or meet.

The **focal length** of a convex lens is the distance along the principal axis from the principal plane or center of the lens to the focal point. Focal length is usually measured in millimeters (mm). Hence, a 35 mm lens is a lens where the focal point is 35 mm from the center of the lens.

PRACTICE

In the following diagram, label the important characteristics of the lens. Write in the labels without looking at the diagram on the previous page. When you have finished, check your labels with those shown on the previous page.

![Diagram of a lens with light rays and focal points labeled](image)
Segment 3 page 3

STUDY PROBLEMS

Fill in the blank spaces with the words *focal length or focal point*.

A magnifying glass is used to focus the sun’s rays to a pinpoint of light on a piece of paper. The pinpoint of light is called the _______ _________.

The distance from the middle of the lens to the point of light is called the _______ _________.

A fat lens bends light rays more than a thin lens. Parallel light rays passing through a fat lens converge at a _______ _________ closer to the lens than do parallel light rays passing through a thin lens. The fat lens has a shorter _______ _________ than the thin lens.

ANSWERS TO STUDY PROBLEMS note 4

DON’T LOOK at the answers until you fill in the blanks.

The first answer in each sentence is focal point; the second in each sentence is focal length. The middle of the lens is the same as the center, where the principal axis passes through the principal plane. Sun rays are parallel rays of light which bend to form a bright spot at the focal point. The thickness of a convex lens determines the distance of the focal point from the center of the lens.

Notes for Segment 3

Remember Generality Concept, Rule 5

Note 1: The presentation should consist of an *expository generality* (*EG*) followed by a single *reference example* (*Eeg*) followed by *practice in paraphrasing* the generality (*IG.P*) (Rule 5a).

NOTE: The reference example (*Eeg*) is presented, first followed by a list of definitions (*EG*), followed by Practice and Study Problems (*IG*) which requires the student to recognize the paraphrase of the definition.

Note 2: The generality (*EG*) should consist of a *definition* of the concept which includes identification of the superordinate class, the relevant attributes which distinguish instances of this concept from coordinate concepts within the same superordinate class, and the relationship of these attributes to one another (Rule 5b). The reference example (*Eeg*) should represent a *typical illustration* of the concept which clearly shows the relevant attributes (Rule 5c). Practice
(IG.P) should provide opportunity for the student to recognize the definition stated in two or more different ways (Rule 5d).

NOTE: The reference example presents alternative views of a convex lens showing the light rays, the primary axis and primary plane. The definition describes the principal plane, principal axis, focal point, and focal length. The superordinate concept for principal plane is imaginary slice, the relevant attribute is location through the center of the lens. For principal axis the superordinate concept is imaginary line, and the relevant attribute is location perpendicular to the principal plane. For focal point the superordinate concept is point, and the relevant attribute is the point at which the light rays converge. For focal length the superordinate concept is distance, and the relevant attribute is the two locations of the principal plane. Notice that practice enables the student to label each of these concepts on the diagram and to use the terms in statements of the definitions.

Note 3: The presentation of the reference example (Eeg) should be accompanied by attention-focusing help clearly indicating each of the critical attributes (Rule 5f). Students tend to remember examples more often than verbal statements, and this reference example will probably be used by the student to reconstruct the definition (Rule 5f).

NOTE: The arrows and words in the diagram illustrating focal point and focal length provide attention-focusing information for the student.

Note 4: Practice (IG.P) should be followed by correct answer feedback (ca+h), which indicates to the student the synonyms involved (Rule 5g).

NOTE: Correct answer feedback is provided in two ways. For the diagram, students are instructed to look back at the original reference example. For the short answer questions students are provided with the correct labels for each question. The feedback would be improved if it is not available until after the students have responded.

Lesson Segment 4

Focal Length and Magnification

Objective: Use-Principle

"Students will explain or predict what effect different convex lenses will have on light rays. Students will explain the way in which the curvature of a lens influences both the magnification and the focal length of different lenses."

Instructional Method: Computer Simulation/Conversational Tutorial

The CDT prescriptions for teaching use-principles could be implemented in many ways, including discovery, simulation, conversational tutorial, or expository tutorial. We have selected a combination simulation/conversational tutorial method using a
computer presentation. We combined the two objectives into a single presentation because we felt that they both required understanding of the same principles. The student is first presented a simulation which enables him or her to change the curvature of a lens and observe the corresponding changes on the image produced. This simulation serves as a set of reference examples to which the subsequent conversational tutorial refers. The student is asked questions about the simulation designed to lead to the statement of the principle. The student is then presented with different situations requiring predictions about the image produced by different lenses and lens combinations. Feedback is provided by allowing the student to see via simulations whether or not the predictions were accurate.

Segment Four

Focal Length and Magnification

This segment is presented in the form of computer assisted instruction. Space and the limitations of the printed page prevent a complete presentation, hence only representative displays are illustrated.

Following the introduction, as seen in Figure 9.4-1, the student is immediately presented a simulation to illustrate the principle being taught (see Figures 9.4-2 and 9.4-3). The simulation is preceded by a brief explanation frame not shown here. notes 1, 2

The student can experiment with the curvature of the lens using the arrow keys. As the curvature is increased, the focal point moves closer to the lens and the focal length gets shorter, as shown by the following display.

The simulation is followed by a conversational tutorial presenting the generalities associated with the principles of focal length and refraction.

![Light Refraction in Convex Lenses](light-refraction-in-convex-lenses.jpg)

**INTRODUCTION**

This segment teaches the principle of light refraction through convex lenses. In this lesson you will learn to:

1. Predict focal length for different convex lenses.
2. Predict magnification for different convex lenses.

Figure 9.4-1. Program introduction frame.
The first two displays direct the student to think about the simulation that was just experienced (Figures 9.4-4 and 9.4-5). If the student is right in his or her observations, the program acknowledges the input and enables the student to continue to the next frame of the tutorial or to return to the simulation. If the student is not correct in his or her observation, he or she is advised to return to the simulation. The student retains control and can return to the simulation or continue the tutorial.\textsuperscript{3}

Figure 9.4-2. Program simulation frame.

Figure 9.4-3. Program simulation frame.
After a series of such displays that quiz the student about observations made while using the simulation, the tutorial then presents more formal statements of the generalities, as seen in Figures 9.4-6 and 9.4-7. These displays are accompanied by questions which serve to direct the student’s attention and cause him or her to process the information presented. \( ^4 \)
The tutorial displays are followed by practice displays requiring the student to predict the focal length of different lenses (Figures 9.4-8 and 9.4-9). When the student answers the question, a RIGHT or WRONG display is provided, then the program draws the light rays to the appropriate focal point to confirm the student's response. The second display shows the light rays after the student's response.
We have presented only part of the segment here. The other parts demonstrate the effect of the lens on magnification. The format of these other segment parts is similar to the first. The student is presented a simulation allowing the manipulation of the lens curvature and observing the effect on a magnified object. Three such simulation displays are presented below. After each simulation the student is presented a conversational tutorial leading to a formal statement of the principles involved. After each tutorial the student is presented practice items asking him or her to predict the relative size of objects as seen through each of the various lens systems. notes 5, 6
Each subsequent simulation presents a slightly more complex arrangement of convex lenses. The microscope simulation involves two convex lenses working together (see Figures 9.4-10 and 9.4-11). The tutorial will help the student observe that the eyepiece magnifies the image resulting from the objective. The student can change curvature for either lens. Note 7

The telescope simulation shown in Figure 9.4-12 complicates the situation further by introducing two kinds of mirrors into the system. The student must first be led to understand that a concave mirror acts like a convex lens. The student must also recognize
that an object seen reflected by a 45° mirror is as if the object were behind the mirror. The simulation and the tutorial will help the student see these modifications. note 8

Figure 9.4-12. Telescope simulation frame.

Notes for Segment 4

Use Principle, Rule 10

Note 1: The presentation should consist of a statement of the proposition (EG), followed by a set of expository examples (Eegs), consisting of several different explanations of specific applications, followed by application practice (legs.N), consisting of several additional applications which require the student to explain or predict relationships (Rule 10a).

NOTE: The simulation presented here varies somewhat from a traditional Rule, Example, Practice format but is still consistent with CDT. The expository generality (EG) is represented by the conversational tutorial represented in the sample lesson by Figures 4-4, through 4-7. The rhetorical questions asked on each of these displays do not constitute practice. They are merely attention-focusing devices to get the student to pay attention to critical aspects of the simulation. Asking a question does not make a primary presentation practice. It is OK to ask questions on expository generality or expository example displays. This point is often a misunderstanding about CDT. The examples (Eegs) are provided by the simulation, shown by Figures 4-2 and 4-3. By giving the student the ability to manipulate the display, the student can actually provide for himself or herself a number of examples. In a sense these examples are matched since only the relevant attribute changes from one to the next. Practice (legs) is provided by a series of questions shown by Figures 4-8 and 4-9.
Note 2: The illustrative explanations (Eggs) should also be elaborated by secondary presentation forms, which provide attention-focusing information clearly indicating the causal or correlational relationships among the component concepts (Rule 10h). This helping information should be faded, that is, gradually decreased, during the later stages of the presentation (Rule 10p). Different explanations should be presented using alternative forms of representation (Rule 10g, 10i).

NOTE: Attention-focusing information is provided in the simulations by arrows and the dynamics of the simulation itself. The student can see the rays bend when changes are made in the thickness of the lens. In practice with the other lens systems, the student is asked to make predictions first prior to manipulating the simulation. This change of order in events increases the amount of mental effort the student must put forth. The instruction would be even more adequate if the system prevented the student from using the additional simulations before he or she made predictions. The representation forms used are all very similar. Perhaps photographs of real lens systems would provide a good alternative representation for the ideas presented.

Note 3: The proposition should be elaborated by means of secondary presentation forms that provide attention-focusing information which helps the student visualize the relationships among the component concepts (Rule 10e). Additional secondary presentations should also review prerequisite information such as definitions or examples of the component concepts (Rule 10f). The proposition should also be restated or represented via some alternate mode such as a graph, chart, diagram, etc. (Rule 10g).

NOTE: Attention-focusing information for the generality consists of rhetorical questions designed to get the student to attend to the relevant parts of the simulation in preparation for observing the action of the principle. The lesson does not review prerequisite information as completely as may be necessary. However, previously-learned concepts are reviewed as part of the rhetorical questions presented in the expository generality phase of the instruction. The proposition is represented both formally in statements and by the reference example simulation provided.

Note 4: The expository generality (EG) should consist of a proposition identifying the principle. This statement of the proposition should clearly indicate the component concepts of which it is comprised and the causal or correlational relationships among these concepts (Rule 10b). Each of the illustrative explanations (Eggs) should consist of a specific situation involving the principle. If some form of representation is used, it must include adequate representation of each of the component concepts involved (Rule 10c). Each of the practice applications (legs.N) should also consist of specific situations or adequate representations of specific situations involving the principle. Further, the practice applications should be different from the illustrative explanations (Rule 10d).

NOTE: The formal statement of the principle appears in Figures 4-6 and 4-7. The component concepts are light rays, a surface between two media of different densities, and the angle at which the rays strike the surface. The causal relationship is between
the angle of incidence and the amount of bend in the light rays. The examples represented by Figures 4-2 and 4-3 contain all of the relevant attributes and the capability for the student to manipulate these parameters and observe the effect on the angle of bend for the light rays. Divergent practice items are provided by having the student predict the occurrence of change in the various lens systems before checking these predictions by using the simulation.

Note 5: The practice applications (legs.N) should also use a variety of representation modes (Rule 10j). Student explanations should be followed by feedback, which provides attention focusing information clearly indicating the causal or correlational relationships that the student should have identified as part of the explanation. This attention-focusing help should not be used prior to the student's response (Rule 10k). The elaboration should also be faded during the later stages of practice (Rule 10u).

NOTE: The practice provides for predictions using a variety of lens systems, but the representation form itself is very similar using schematic diagrams. The feedback is allowing the student to check the predictions by manipulating the simulations. This feedback contains all of the attention-focusing devices of the original presentation.

Note 6: Each of the primary presentations (Eg, Egs, and legs.N) should be isolated from surrounding text and related information so that the main ideas and key points of the explanations are easily identified by the student (Rule 10m).

NOTE: Isolation is provided by labels indicating the principle and practice. The examples and subsequent practice are less carefully isolated but could be by requiring the students to make predictions and clearly indicating that this is necessary before they can use the simulation to check their work.

Note 7: Subsequent explanations for both the examples (Egs) and practice (legs.N) should be divergent from one another so that the student is exposed to a variety of situations to which the principle is applicable. This prescription facilitates generalization to subsequent events or situations which are explained by the principle being taught (Rule 10l).

NOTE: Divergence occurs when different lens systems are used for subsequent predictions. Each requires some modification in the application of the principle.

Note 8: In both the explanation (Egs) and prediction (legs.N) phases of the instruction, the situations selected for illustration should represent a wide range of difficulty. That is, in some situations the application of the principle should be more obvious while in others the application may be more subtle. This procedure increases the student's ability to apply the principle to a wide variety of situations following the instruction (Rule 10r).

NOTE: The practice simulations increase in difficulty by introducing more and more complex lens systems. Each simulation is more difficult than the last.
Note 9: Illustrative explanations should include those for common misconceptions. The student should be shown where the principle does not work or situations to which the principle does not apply. This procedure assists the student to be discriminating in the application of the principle to subsequent situations (Rule 10p). In later stages of the presentation and in practice the student should be asked to identify inappropriate applications of the principle. Practice that asks the student to explain a given situation is better than having the student choose between an appropriate and inappropriate application or explanation (Rule 10q).

NOTE: This lesson does not implement this principle. Perhaps showing the student some of the common mistakes in reasoning about the bending of light rays would be useful.

Lesson Segment 5

Using the Microscope

Objective: Use Procedure

"Students will be able to use a previously unencountered optical microscope properly."

Instructional Method: Video Disc

Demonstrations for Use Procedure objectives that follow CDT prescriptions can involve a wide variety of instructional techniques. Because the lesson fragment included must be presented on the printed page, it is demonstrated using a story board. Representative frames of the presentation are steps of the procedure frozen in time. The actual presentation would consist of either a film strip, slides, or computer screens using a series of still pictures. If resources are available the pictures could be video sequences on a VCR or an interactive video disc. We have described part of an interactive video disc sequence. The major steps of the process are first illustrated to provide the big picture. Then a series of pictures and captions explains each step in the procedure. Adequate practice for this skill is not possible using only the demonstration; subsequent practice would be provided in a laboratory where the student has access to equipment of the type being demonstrated.

Segment 5

Using the Microscope:

A Specification for A Videodisc Demonstration

There are two parts to the lesson on using the microscope. Part 1 is a video disc demonstration which shows the student how to use the microscope. The unique feature of the demonstration is that the student can repeat any step or substep as many times as necessary. The following flowchart (Figure 9.5-1) shows the structure of this video disc demonstration. The numbers and letters (1a) refer to the section of the script that corresponds to the procedure identified in the diagram.

The following segment of a script corresponds to this structure diagram and will provide more detail concerning this demonstration. Note the following characteristics of
the demonstration: The demo first lists the steps for the student. The overview menu allows the student to view a short action segment corresponding to each step. The overviews can be viewed in any order and as many times as the student wishes. Selecting Details from the menu takes the student to a detail menu for that step, which first lists the steps and then allows the student to view a detailed demonstration for each substep in any order and as many times as necessary. Selecting Overview returns the student to the Overview menu.

Figure 9.5-1.

Script for Microscope Demonstration

1a. INTRODUCTION

Music—

[Overview menu is on the screen. Picture shows microscope.]

NAR: In this segment of the course we will demonstrate how to use a simple optical microscope. You can view this demonstration at your own pace. To repeat a given
section, press the arrow keys to select the step (Highlight the directions “Arrows to Select” on the screen). To move to the selected part of the demonstration, press the SPACE bar. (Highlight the directions “SPACE BAR to CONTINUE” on the screen.) If the overview box is selected when you press the space bar, you will see an overview of the step. If the details box is selected when you press the space bar, you will be shown the substeps involved in the step which is selected. It is usually wise to view the overview before you view the details for a step. You may repeat any part of the demonstration by selecting the step using the arrow keys and pressing the space bar. When you are ready to begin, please press the space bar.

1b. LIST THE STEPS note 2

Music—

NAR: There are four major steps in using a microscope.

[Highlight step name “1. PREPARE SPECIMEN.” A still picture represents the step.]

First, you must prepare the slide.
The slide will contain the specimen which we wish to view under the microscope.

[short pause]

[Highlight “2. SET UP MICROSCOPE” with still picture.]

Second, you must set up the microscope by mounting the slide and adjusting the light.

[short pause]

[Highlight “3. ADJUST MICROSCOPE” with still picture.]

Third, you must adjust the microscope so that the specimen is in focus. [short pause]

[Highlight “4. OBSERVE SPECIMEN” with still picture.]

Fourth, you may now observe the specimen. [short pause]
2a. DEMO OF STEP 1  

[Picture of assistant with microscope and apparatus on the table.]  
NAR: This is my assistant, Eric. He will demonstrate the use of the microscope for us. Eric will show us each of the major steps in the use of the microscope.  
[Highlight the name of the step “PREPARE SPECIMEN.”]  

[In the picture area of the screen, a motion sequence shows Eric get the glass slide from the case, wash the glass slide, get the sample of pond water to be used, use the eye dropper to place the pond water on the slide, spread the drop with the cover glass, and slip the cover glass in place.]  
NAR: [Synchronize narration with demonstration.] First, Eric will show us how to prepare a slide. He first washes the slide to remove any foreign matter and allows it to air dry. [Pause to allow action sequence to be completed.] He then places a drop of pond water on the slide containing the specimen we want to observe. [Pause as necessary.] The specimen is spread thin and covered with the cover glass. [Pause as necessary.] We will show you the details of each of these steps later in this demonstration. [Pause]  

[Demonstration to freeze frame as Eric turns toward the microscope with slide in hand.]  

2b. DEMO of STEP 2  

[Highlight the name of the step “SET UP MICROSCOPE.”]  

[In the picture area of the screen, a motion sequence shows Eric getting the microscope, carefully cleaning the lenses with lens paper, positioning the scope for easy viewing, adjusting the light and the mirror so that they are directed onto the objective, and carefully placing the slide on the stage of the microscope.]  
NAR: [Synchronize narration with demonstration.] Next Eric demonstrates how to set up the microscope. The lenses should be carefully cleaned with lens paper. [Pause] The microscope is positioned for easy viewing with the arm toward him. [Pause] He then adjusts the light. Adjusting the light is one of the most important steps since without proper adjustment he will be unable to see the specimen. [Pause] He now places the slide carefully on the stage of the microscope to avoid disturbing the adjustment in the light. [Pause]  

[Demonstration to freeze frame with Eric getting ready to adjust microscope.]  

2c. DEMO of Step 3  

[Highlight the name of the step “ADJUST MICROSCOPE.”]  

[In the picture area of the screen, a motion sequence shows Eric selecting the lowest magnification objective; he then uses the course adjustment to lower the objective almost to the cover glass while observing from the side. Then, while looking through the eyepiece, he uses the fine adjustment to bring the specimen into focus.]  
NAR: [Synchronize narration with demonstration.] Now Eric is ready to make the final adjustments so that he can observe the specimen. First, he selects the proper objective, in this case the one with the lowest power of magnification. [Pause] Then, using the course adjustment knob, he carefully lowers the objective down until it almost touches the cover glass. [Pause] While looking through the eyepiece, Eric now uses the fine adjustment knob to bring the specimen into focus. [Pause] He is now ready to make observations of the specimen. [Pause]
(Demonstration to freeze frame with Eric moving forward to look into the eyepiece of the microscope.)

2d. DEMO of STEP 4

{Highlight the name of the step "OBSERVE specimen."}

{In the picture area of the screen, a motion sequence shows Eric looking through the eyepiece of the microscope. The picture then changes to show what Eric is seeing, then Eric looks at a picture in the textbook and makes notes on a pad about the specimen he is observing. This observe-the-specimen, look-at-the-textbook and write-notes sequence is repeated three times before the sequence stops.}

NAR: {Narration in synch with demonstration.} Eric is now ready to use the microscope to observe the specimen. He looks through the eyepiece. {Pause} The screen now shows what Eric sees in the drop of pond water. {Pause} Eric has been assigned to draw pictures of all the different organisms that he observes. He is making sketches and comparing them to the illustrations in the textbook to try to see if he can identify the different forms of organisms. {Pause}

{Demonstration to freeze frame with Eric looking through the eyepiece.}

3a. STEP ONE (PREPARE specimen)
SUBSTEPS notes 5, 6

{Detail menu is on the screen.}
Chapter 9: Lesson Segments Based on Component Display Theory

{Highlight step name "PREPARE specimen."}
{Still picture shows close-up of table including jar of pond water, box of slides, cover glasses.}

NAR: Eric and I will now show you the first step in more detail so that you will know exactly what to do when you get to the laboratory. You will recall from the overview that the first step is to prepare the specimen. In this demonstration our specimen will be small organisms present in some stagnant pond water which was previously collected in this jar.

{Still picture shows close-up of the jar in the context of the table shown in the previous picture.}

Preparing the specimen requires several substeps:
{Highlight first substep, "Clean Slide."}
{Show still picture of Eric washing slide.}
The first substep is to be sure that our slide is clean so that our specimen won’t be contaminated by organisms already on the slide. {Pause}
{Highlight second substep, "Place Specimen on Slide."}
{Show still picture of eye dropper placing drop on slide.}
Next we must place the specimen on the slide. In the demonstration we will place a drop of pond water on the slide. {Pause}
{Highlight third substep, "Provide Thin Cross Section."}
{Show still picture of drop spread thin by cover glass.}
In order to see the specimen, it must be very thin. The cover glass is used to spread the drop into a thin film on the slide. {Pause}
{Highlight fourth substep, "Protect with Cover Glass."}
{Show still picture of cover glass in place on slide.}
The cover glass serves to protect the specimen and to protect the lens in the objective of the microscope. {Pause}

3b. STEP ONE, Substep 1, Clean Slide note 7
{Highlight first substep, "Clean Slide."}
{Action sequence shows Eric removing slide from slide tray, washing the slide very carefully by rubbing it between his thumb and forefinger, rinsing it with very hot water while holding it by the edges, and placing it in the rack to air dry. All of the photography is close-up of the slide and his hands, whereas the previous overview was farther back.}

NAR: {Narration in synch with the presentation.} It is very important to use a clean slide. If the slide is not clean, we may be observing organisms or material that was already on the slide rather than that which came from the specimen. Eric is demonstrating the procedure we will use to clean the slide in our laboratory. Note that he scrubs the slide carefully between his thumb and his forefinger to remove any material that may cling to the glass. Also note that he is using a disinfectant soap that will destroy most microorganisms that may be on the slide. After he scrubs the slide with the disinfectant soap, he rinses it carefully with very hot water while holding the slide by the edges to avoid placing fingerprints or organisms from his fingers on the clean slide. He then places the slide in the rack to air dry. If he were to use a cloth to dry the slide, he would likely place material or organisms from the drying cloth on the slide.

{Action sequence showing someone else in a lab coat placing microscope slides in a sterilizer.}
In laboratories where accurate observation is very important, the slides are sterilized after they are thoroughly washed. The sterilization process heats the surface of the slides, killing any microorganisms that may still be present. For our purposes sterilization is not necessary; we will merely wash our slides very carefully, as is demonstrated by Eric.

3c. **STEP ONE, Substep 2, Mount Specimen**

{Highlight second substep, “Mount Specimen.”}

{Action sequence showing Eric carefully removing the lid from the jar of pond water and using the eye-dropper to place a single drop of the liquid on the slide.}

**NAR:** In our demonstration we will be observing organisms present in stagnant pond water. The jar of pond water was previously gathered from a nearby pond that is rich in algae and other life forms. Eric carefully places a single drop of the pond water on the slide.

{Action sequence showing someone other than Eric placing various kinds of samples on a slide.}

**NAR:** Many different kinds of specimens can be observed under a microscope. Some of these represent thin slices of tissue from animals or plants. {Action sequence illustrates tissue slices.} Other specimens are crystal structures best observed by grinding the specimen to a fine powder. {Shows the grinding of a mineral to a powder which is then placed on the slide.} Often it is necessary to stain the specimen with special dyes in order to observe its shape or structure. {Shows technician placing dye on a specimen.} The preparation of specimens for observation under a microscope is a special branch of science in itself. For our introduction we will merely use simple techniques, such as the drop of pond water which we have illustrated.

{The script continues for other substeps. Space prevents the inclusion of the entire script here.}

**Part 2 notes 8, 9**

After the video disc demonstration the student is allowed to experiment with an actual microscope in the laboratory. This is a series of laboratory exercises which really involves backward chaining. That is, the student first does only the last step, the previous steps having already been completed by the lab assistant. Each successive exercise adds to the previous step until finally the student does all of the steps necessary in using a microscope.

The ideal way to use the video disc demonstration and the laboratory is to integrate the two as follows. First the student sees the overview (1a, 1b, 2a through 2d). Then the student views the detailed presentation in 6a through 6e concerning how to observe through the microscope. Then the student goes to the lab and completes the first lab exercise requiring only observation through a previously set up microscope. The next experience would be to view the demonstration 5a through 5e and to review parts of 6 that might be unclear. Then do the second laboratory exercise, etc. Thus the demonstration and lab experience are more integrated. Unfortunately most school situations may make such an arrangement difficult or impossible.

When the student gets to Step 1, preparing slides, there should be opportunity to work with different kinds of specimens and to prepare a variety of types of slides for observation. If the class is in biology, mineralogy, or general science, then these additional practice experiences could be integrated as part of the remaining curriculum rather than as special exercises in the use of the microscope. After this demonstration and
initial practice, the microscope should be integrated into the curriculum as a tool, thus providing the variety and additional practice necessary.

\begin{center}
\begin{tikzpicture}
  \node (start) [startstop, rounded corners] {Start};
  \node (observe) [process, below of=start] {Observe};
  \node (adjust) [process, below of=observe] {Adjust Observe};
  \node (set_up) [process, below of=adjust] {Set Up Adjust Observe};
  \node (prepare) [process, below of=set_up] {Prepare Slide Set Up Adjust Observe};

  \draw [arrow] (start) -- (observe);
  \draw [arrow] (observe) -- (adjust);
  \draw [arrow] (adjust) -- (set_up);
  \draw [arrow] (set_up) -- (prepare);

  \node (note1) [below of=observe] {Microscope is all set up with slide in place. Student is asked to observe and draw what is seen.};
  \node (note2) [below of=adjust] {Microscope is set up with slide in place but student must first adjust the objective and then observe and draw what is seen.};
  \node (note3) [below of=set_up] {Slide is prepared but student must set up the microscope, place the slide on the stage, adjust the microscope, and observe and draw what is seen.};
  \node (note4) [below of=prepare] {Student must prepare the slide. After the slide is prepared, student must set up the microscope, place the slide on the stage, adjust the microscope, observe the slide, and draw what is seen.};
\end{tikzpicture}
\end{center}

Figure 9.5-4.

\section*{Notes for Segment 5}

\textbf{Use Procedure, Rule 9}

Note 1: The presentation should consist of a general description of the activity (EG), followed by demonstrations with specific objects (Eegs), followed by opportunities for the student to demonstrate the procedure with a similar but different object and/or materials (legs.N) (Rule 9a).

\textbf{NOTE:} The description of the activity is represented by Figure 9.5-2 and script 1b which shows each of the major steps. At the next level down this same procedure is followed by representing the steps within a major step as a list (see script 3a). The demonstrations show each of the major steps (script 2a, 2b, 2c, and 2d), and later demonstrations show each of the substeps within each of the major steps (script 3b, 3c,
etc.). This lesson uses elaboration theory, as described in the chapter by Reigeluth, by presenting the major steps first and then elaborating the detail. Finally, using backward chaining (another application of elaboration theory), the student is asked to demonstrate his or her ability to use the microscope (see Part 2).

**Note 2:** The generality (EG) should consist of a description of the activity which identifies the outcome that will result from following the procedure, indicate each of the steps and their order of execution, and indicate each of the decisions required and the resulting branches (steps) following the various alternatives from these decisions. The demonstrations (Egs) should show how to perform each of the steps and how to make appropriate decisions. If the demonstration is a representation rather than “hands on,” this representation must be sure to clearly illustrate each of the steps, the proper sequence for execution, and the expected consequence of each step (Rule 9c). The practice demonstration (legs,N) should enable the student to execute each of the steps. If possible, this execution should use objects and materials involved or simulation of such objects and materials. If the procedure being taught will be used with a variety of objects and materials, the student should have an opportunity to practice with different objects and/or materials (Rule 9d).

**NOTE:** Script 1b presents the steps at the main level, script 3a illustrates generality for substeps. Scripts 2a through 2d demonstrate the major steps; scripts 3b, 3c, etc., demonstrate the substeps. Part 2 enables the student to execute each of the main and substeps.

**Note 3:** The description of the activity (EG) should be elaborated by secondary presentation forms which help the student remember the individual steps and the sequence required for execution (Rule 9e). When decisions involve previously learned concepts or facts, the secondary presentations should review generalities and/or instances of these prerequisite ideas (Rule 9f). If possible the procedure should be described and illustrated via some chart, diagram, picture, or other illustration to present at least two alternative representations of the activity (Rule 9i).

**NOTE:** Arrows, voice over, a surrogate student, or an assistant on the screen all provide the attention focusing required. Some prerequisite ideas are introduced as part of the script.

**Note 4:** The demonstrations (Egs) should also be elaborated by secondary presentation forms which clearly identify each step as it is being executed. This information should also focus the student’s attention on the decisions required and the consequences of these decisions (Rule 9h). A second demonstration should fade this attention-focusing information, requiring the student to attend more closely to the task (Rule 9q).

**NOTE:** The narration and video clearly focus the student’s attention on the relevant aspects of the procedure. The practice fades much of this detailed attention focusing.
Note 5: During the demonstration the student should be shown common incorrect ways to perform the steps or make the required decisions. These incorrect paths should be clearly labeled and the student given sufficient warning to avoid these incorrect procedures. Clearly identifying and illustrating incorrect paths help students avoid such mistakes during their own practice (Rule 9p).

NOTE: This prescription has not been implemented as well as it might be. During the demonstration some cautions may be very appropriate. For example, getting a fingerprint on the slide by not handling it by the edges, damaging a slide by using the course adjustment knob while looking through the scope, not getting the light focused correctly, etc. Showing these common mistakes and adding a caution will help the student avoid them.

Note 6: The description of the activity should be concise and to the point. Critical steps and actions should be clearly separated from elaborative information (Rule 9m).

NOTE: The title slides and text on screen provide the necessary isolation of critical parts of the procedure. Single word labels for each of the steps enable the student to remember the most important aspect of each step.

Note 7: If the activity involves both simple and more complex means of execution, the range of such operations should be illustrated during the demonstrations, and the student should have an opportunity to practice both the straightforward and the more complex forms of the procedure (Rule 9l).

NOTE: The range of procedures is illustrated during the demonstration to show the student sterilization procedures, various ways to prepare a specimen, etc. Even though the student will not be required to use these more advanced procedures, they are illustrated to show him or her the range of possibilities. Some range of activity is included in this lesson, but the real range of activity will come as the microscope is used during the course.

Note 8: Opportunities for the student to demonstrate the activity (legs N) should include several tries using a variety of equipment and materials (Rule 9j). During the early practice tries, correct answer feedback should be immediate and precise indicating to the student steps omitted, steps performed incorrectly, decisions omitted or incorrect, etc. (Rule 9k). Later stages of practice should let the consequences of the student's actions provide the feedback concerning adequate performance (Rule 9t).

NOTE: Limitations in equipment available would probably limit the variety of experience that could be provided. In this case the student may use the same microscope but could certainly have a variety of experience with different slides and specimen.
Note 9: If the real world, where the procedure will be used, involves different types of equipment and materials, then the student should see a variety of equipment demonstrated and should have the opportunity to practice on a variety of equipment (Rule 9).

NOTE: If different microscopes are not available, at least a variety of specimen could be examined requiring different preparation of slides, different objectives for viewing, etc.