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TECHNICAL AND TUTORIALS

Creating the Components for Teaching Concepts

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Abstract
An important dimension of Direct Instruction (DI) programs involves teaching conceptual behavior related to broadly applicable generalizations of a content domain. The current article outlines the necessary components for teaching a concept in any domain. The first step (1) is to conduct a concept analysis of the critical features that define the concept, as well as the features that vary from instance to instance of the concept. From this prescription we must (2) develop a range of typical and far-out examples of the concept that illustrate both the critical and variable features, (3) develop a minimum rational set of close-in nonexamples of the concept, each of which is missing only one critical feature, (4) develop matched example/nonexample pairs to highlight the critical feature missing in each example, and (5) develop additional examples and nonexamples that may be needed to produce the desired discriminations. Multiple exemplar teaching is not enough. Teaching a concept this way produces generative responding to examples as well as nonexamples not presented during instruction. To assess learners' generative responding, we must (6) create another set of far-out examples and close-in nonexamples from the concept-analysis prescription. Finally, after initially acquiring conceptual behavior, learners must (7) practice with additional far-out examples and close-in nonexamples. Once these components are created, a teacher is ready to develop an instructional sequence featuring tasks that include context-setting descriptions, rules, examples, and nonexamples.

Keywords Instructional design · concept learning · generative responding

Conceptual learning is one of nine types of learning identified by Tiemann and Markle (1990), and one of seven types that Engelmann describes in his theory of instruction (Becker, 1986; Engelmann & Carnine, 1991). Unlike more basic cognitive behaviors such as motor responses, stimulus–response pairs, behavior chains and sequences; when we teach concepts, principles, rules, and strategies, learners must be able to respond to a range of stimuli and events that were *not* presented in instruction. We call the repertoire the learner acquires *generative responding*, and the methods used to teach it, *generative instruction* (Johnson et al., 2020). In this article, we will outline the tasks an instructional designer must create in order to design an instructional sequence for teaching a concept and related conceptual behavior. In the next article, Janet Twyman will describe how to design an instructional sequence using these tasks. Our discussion will use terms and concepts not only from Direct Instruction (e.g., Engelmann & Carnine, 1991), but also from the programed instruction literature on teaching concepts (e.g., Markle & Tiemann, 1969, 1974; Tiemann & Markle, 1990). We will begin by defining *concept* and *conceptual behavior*.

What is a Concept? What is Conceptual Behavior?

A concept is a class of stimuli or events with *certain critical features* (Tiemann & Markle, 1990). Each member of the concept class contains these key features. In his tutorial on teaching concepts, Layng (2018) calls them *must-have* features. Each member of the concept class also has other features that vary across the members of the class: *variable features*. Layng calls them *can-have* features. When asked to identify a concept, we respond with the concept name when a stimulus or event illustrates certain critical features, in a context of other features that vary from instance to instance (Johnson et al., 2020).

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Examples of conceptual behavior include naming various shapes of objects; for example, circle, square, and triangle. Learners demonstrate conceptual behavior when they say, "That's a circle," regardless of its color or size. We can ask a learner to circle the nouns in sentences. The learner circles the noun in a sentence while exclaiming, "That's a noun," regardless of which specific noun she reads in a sentence. Naming a book a *biography* or an *autobiography* also illustrates conceptual behavior, as does naming objects in a kitchen, and even naming a painting *impressionist*, *cubist*, or *abstract expressionist*. The learner says, "That's a cubist painting," regardless of which cubist painting he sees. Naming a description of a government *socialism* or *democracy* also illustrates conceptual behavior. The learner says, "That paragraph describes a socialist government," regardless of the variable features of the particular socialist government that they read about (Johnson et al., 2020).

Concept Analysis

To teach a concept we conduct a *concept analysis* (Layng, 2018; Tiemann & Markle, 1990). First, we determine the critical features of the concept. Let's analyze the critical features of the concept *bicycle*. A bicycle has (1) two wheels held in a frame one behind the other length-wise, (2) a steering handle attached to the front wheel, and (3) two foot pedals that the rider uses to power or propel it. If any critical features are absent, we have a nonexample. The best nonexamples are missing only one critical feature. We call them *close-in nonexamples* (Tiemann & Markle, 1990). Examine Fig. 1. Can you tell which feature is missing in each close-in nonexample picture?

Some nonexamples have more than one critical feature missing. For instance, *wagon* has four wheels consisting of two tandem sets; a bed that seats one or more people; and no foot pedals. A wagon illustrates feature 2 (steering handle attached to front wheels) but is missing the other two critical features: feature 1 (two wheels), and feature 3 (foot pedals). Therefore, it cannot be a close-in nonexample of a bicycle because it is missing more than one feature. We call it a *far-out nonexample* (Tiemann & Markle, 1990). Teaching with only far-out nonexamples may lead a learner to say *bicycle* in the presence of close-in nonexamples of bicycles, like tricycles and scooters. We may begin concept instruction with typical far-out nonexamples of the concept, but we need to quickly focus on close-in nonexamples.

To teach a concept we need at least one close-in nonexample for each critical feature. The concept *bicycle* has three critical features, so we need at least three close-in nonexamples, one for each critical feature. This is called a *minimum rational set of nonexamples* (Tiemann & Markle, 1990). Some learners will need many more than one of each. The number of nonexamples we need is an empirical, not a rational, question. To design a concept program, Markle (1967, 1990) suggests that designers begin with instruction that contains only a minimum rational set of nonexamples—a *lean program*—then try it out with a few vocal individual learners who represent the learners we will be teaching. They will help us discover the number of nonexamples we should include in the first official program try-out.

In a concept analysis, we also specify those features of a concept that vary from instance to instance of the concept. Variable features are those features that change from example to example (Tiemann & Markle, 1990). Variable features for the concept *bicycle* are the materials used to make the frame, seat(s) and pedals; the number of seats, none to a few; the size of the wheels; whether the wheels are the same size or different sizes; and the color of the frame, seat(s), and pedals. Of course, examples of bicycles may also include variations that are irrelevant to a learner distinguishing between bicycles and nonbicycles, such as scratch marks and other idiosyncrasies, which you can ignore in your concept analysis. When we teach a concept, we present a *fully divergent set of multiple examples* of the concept (Tennyson et al., 1972; Tiemann & Markle, 1990). Figure 2 illustrates a range of examples of the concept *bicycle*. Figure 3 illustrates a range of examples of the concept, *puppy*. Figure 4 illustrates a range of examples of the concept *fruit*. A set of examples is fully divergent when some examples have no variable features in common with other examples (Tennyson et al., 1972). We must create three different fully divergent sets of examples: one for instruction, one for practice, and one for assessment (Johnson et al., 2020).

Like most things in science, there is no "absolute truth" about the number of features described in a concept analysis. Critical features for every concept are dependent on the verbal community in which they are used. For example, although some may not think there is a difference between different styles of shoes, some of our colleagues in Italy would beg to differ! The only way to know if your analysis is complete is to test it with your learners. Your concept analysis can only be called effective if it produces the changes in behavior you wish to see in your instructional program. For example, Johnson's (2014) concept analysis of a bicycle differs slightly from the one we present. Each analysis would yield slightly different sets of examples and nonexamples. Thus, the only way to compare the effectiveness of each analysis would be to test them with learners. Likewise, the number of variable features included in your analysis could be seemingly endless. The number of variables features you include may also vary depending on how your learners respond to your analysis.

Fig. 1. The Minimum Rational Set of Nonexamples for the Concept *Bicycle.* Images retrieved from: https://www.unicycle.com/hoppley-16-unicycle/, https://www.bikehighway.com/tomcat-bullet-apprentice-single-speed-special-needs-adult-tricycle.html, https://www.globber.com/us/scooters-for-teens-boys-girls/85-962-FLOW-FOLDABLE-125.html, https://www.goodhousekeeping.com/health-products/a32600106/where-to-buy-bicycles-online-best-stores/, https://www.harley-davidson.com/us/en/motorcycles/softail-standard.html

Fig. 2. A Divergent Set of Examples for the Concept *Bicycle.* Photos courtesy of Three Oaks Bicycle Museum, Three Oaks, MI

Fig. 3. A Divergent Set of Examples for the Concept *Puppy*. Retrieved from https://indieadco.com/

Multiple Exemplar Teaching is Not Enough

One example is not enough. We cannot teach the concept *red* or *square* by presenting one example. The learner may learn to say *red* or *square* in the presence of a particular red thing, or a square of a certain size, but they are not learning the concepts *red* or *square*. They may not call a larger sized red object *red*. They may not call a smaller sized square a *square* (Engelmann & Carnine, 1991; Tiemann & Markle, 1990).

In fact, even multiple exemplar instruction is not enough. If you teach only with examples and no nonexamples, the learner may not learn the boundaries of the concept class or domain (Engelmann, 1969). To avoid red responses to pink things, the concept program must include close-in nonexamples of *red*, such as pink nonexamples, which lie just over the boundary of the concept class *red*. They may also call a rectangle a *square*. To avoid such errors, instructional designers must include close-in nonexamples of squares, such as rectangle nonexamples, which lie just over the boundary of the concept class square (Tennyson et al., 1972). From a stimulus control perspective, Tiemann and Markle (1990) and Engelmann and Carnine (1991) provide a more systematic process than the original behavior analytic recommendation by Stokes and Baer (1977) to include multiple examples when teaching for generalization.

Fig. 4. A Divergent Set of Examples for the Concept *Fruit*. Retrieved from https://jorgensenfoods.com/category/fruits

Matched Example/Nonexample Pairs

When first learning a concept, many elementary and naïve learners benefit from starting with a set of *matched example/nonexample pairs*. The only difference between the example and close-in nonexample in a matched example/nonexample pair is the missing critical feature. Developing additional examples or nonexamples that illustrate matched pairs helps reduce the chance that a learner will mistakenly confuse a variable feature for a critical feature, which aids conceptual learning (Tennyson et al., 1972; Merill & Tennyson, 1992).

The four images at the top of Fig. 5 displays two example/nonexample pairs for teaching the concept *square*. The first pair on the left is a *matched* example/nonexample pair. Notice that the variable features are held constant; the size, color, and outlines are all the same. In this matched pair, it is easier for a naïve learner to discern that the difference between the example and nonexample is the length of the sides. Now, let's investigate the other example/ nonexample pair for square. The shape used as an example differs from the nonexample in size, is colored with a pattern, and is darkly outlined. The pair is not matched. By varying all of these features, the learner may incorrectly learn that a square is (1) something that has a pattern, (2) an item that is smaller than something else, or (3) a darkly outlined shape.

Notice that learning these three errors about squares illustrates both naming nonexamples as examples, and naming examples as nonexamples.[1] When a learner makes both types of errors, we say that they have learned a misconception (Tiemann & Markle, 1990). Let's consider another illustration to make our point. A student presented with a divergent set of examples of fish that includes only angelfish, goldfish, and beta fish may erroneously learn that any creature that is in a household aquarium is a fish. They may exclude tuna, grouper, and catfish, because they are not typically in a household aquarium. They may also tact other items that can typically found in a household aquarium as fish, such as turtles, slugs, and octopi!

We can be proactive and account for this in our instructional design by using matched pairs at the beginning of an instructional lesson. Figure 5 presents examples/nonexamples pairs for the

[1] Tiemann and Markle (1990) consider naming nonexamples as examples instances of "overgeneralization," and naming examples as nonexamples instances of "undergeneralization," although we do not prefer these terms.

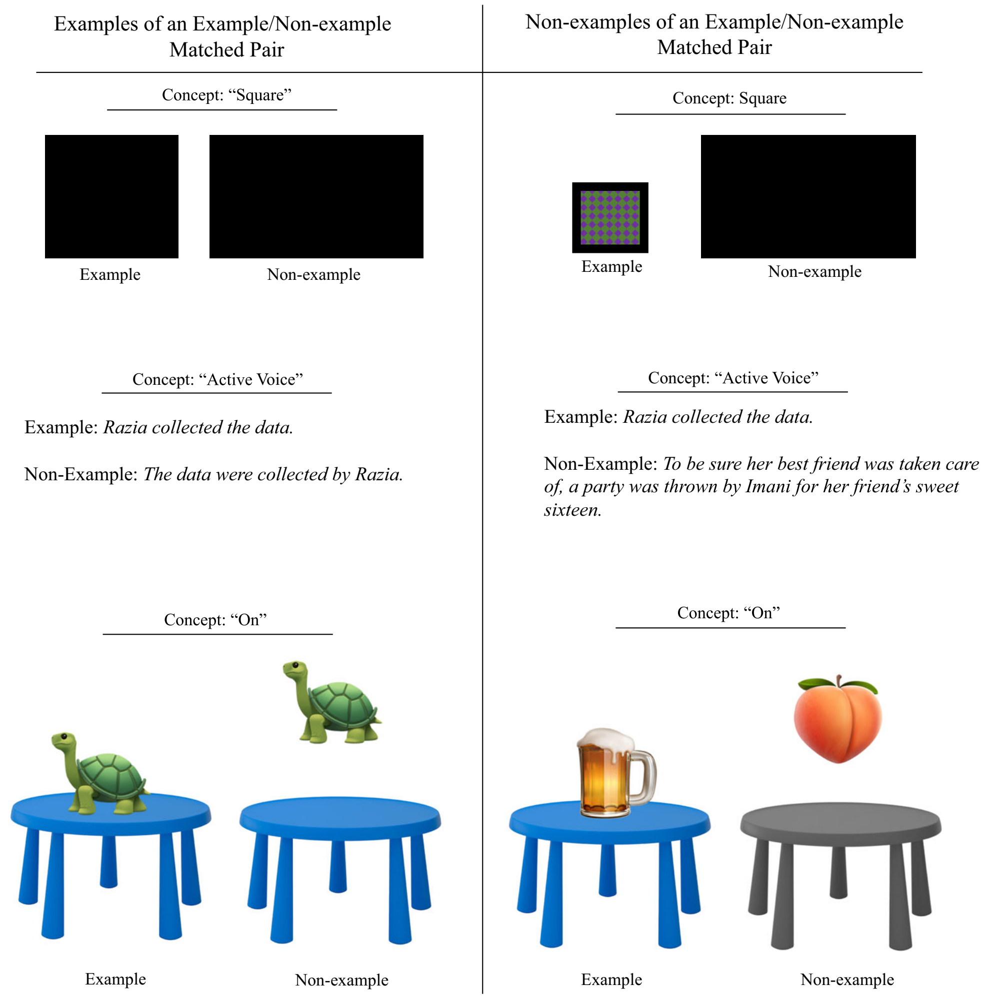

Fig. 5. Examples and nonexamples of matched pairs

concept of *active voice.* This example further highlights how an instructional designer can account for misconceptions early on. In the first instance, the pair is matched. The only difference between the example and nonexample is that the subject of the sentence performed the action, rather than received it. In the nonmatched pair, the instructional designer varied too many variable features. This may make it difficult to identify the important difference between the two sentences.

Take a look at the second set of images at the bottom of Fig. 5 that were selected to demonstrate the concept of *on.* In the first matched pair, all variable features are held constant; the turtle is *on* the table in the example and is *not on* the table in the nonexample. Can you describe the types of misconceptions that may occur if we used the third nonexample set to teach the concept *on*?

Teaching the General Case of the Concept, Van Gogh's Painting Style

Engelmann characterized teaching with a fully divergent range of examples, plus at least a minimum rational set of close-in nonexamples, *teaching the general case* (Engelmann & Carnine, 1991). Let's take a look at these components in action including some divergent examples, and a minimum rational set of nonexamples for teaching the general case of the concept, *Van Gogh's Painting Style.*

One of Tiemann and Markle's students conducted a concept analysis of Van Gogh's painting style, presented in Table 1. Van Gogh's painting style has three critical features:

Table 1. A Concept Analysis of Van Gogh Style

Concept Analysis	
Critical Features	Variable Features
CF 1. The forms are darkly outlined CF 2. The colors used are intense in tone CF 3. The brush strokes are energized	VF 1. Subject a. Portraits b. Landscapes c. Still Life VF 2. Color scheme a. Cool Colors b. Warm Colors

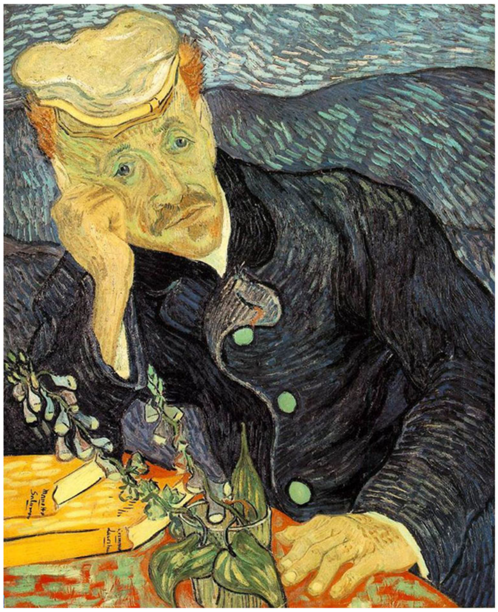

Fig. 6. Van Gogh's *Portrait of Dr. Gachet.* Retrieved from https://en.wikipedia.org/wiki/Portrait_of_Dr._Gachet

(1) the forms are darkly outlined, (2) the colors used are intense in tone, and (3) the brush strokes are energized (Tiemann & Markle, 1990). Some readers may think that we should operationally define these features, but we find that examining paintings while describing and pointing to these features does the trick.

The variable features in Van Gogh's painting style include subject matter and color schemes. He painted three different subjects: (1) portraits, (2) landscapes, and (3) still life, such as a table setting. His color schemes included both (1) cool colors and (2) warm colors.

Ready to inspect and analyze some paintings? First, we'll examine some examples of Van Gogh's painting style. Remember, examples illustrate the variable features. Then we'll examine some close-in nonexamples painted by other artists, each missing only one critical feature.

Space does not permit us to analyze a fully divergent set of examples, so the three paintings in Figs. 6, 7, and 8 must suffice. Figure 6 shows a portrait example, *Portrait of Dr. Gachet*, with both warm and cool colors. Notice that the person in the portrait is darkly outlined—the first critical feature—in particular the man's jacket, the books, the leaves of the flowers, and the couch he is sitting upon. The colors are also sharp, vivid, saturated, and distinct from each other, and juxtaposed against clearly different colors, creating intensity in tone, the second critical feature. Finally, Van Gogh's brush strokes are visible and call attention to themselves, with no attempt to mask them as one would paint a portrait that looks more like a photograph. We say those kind of brush strokes are energized, the third critical feature.

Figure 7 shows a landscape example of Van Gogh's painting style, *Wheatfield with Crows*, with both warm and cool colors. Notice that the forms are darkly outlined, in particular the birds and the road between the wheat fields. The colors used are also intense in tone, distinct from each other, with saturated blue, green, brown, and his favorite color, yellow, juxtaposed against each other. The brush strokes also obvious and energized.

Figure 8 is an example of Van Gogh's still life painting, *Vase with Sunflowers*, with both warm and cool colors. The forms are darkly outlined, in particular the vase and the line between the floor and wall. The colors are also intense in tone, with clear saturated blue and orange, distinct from each other. Finally, the brush strokes are obvious and energized, creating rough effects on the wall and table, and fuzzy distinctions among the flowers in the middle of the vase, not like a photograph.

Now let's examine a minimum rational set of three close-in nonexamples of paintings by other artists. Figure 9 shows the first nonexample, *Water Lilies,* by Monet. Although the painting illustrates both color intensity and energized brush strokes—critical features 2 and 3 of Van Gogh's painting style—the lily pads and other plants in the pond are definitely not darkly outlined, so it is missing critical feature 1.

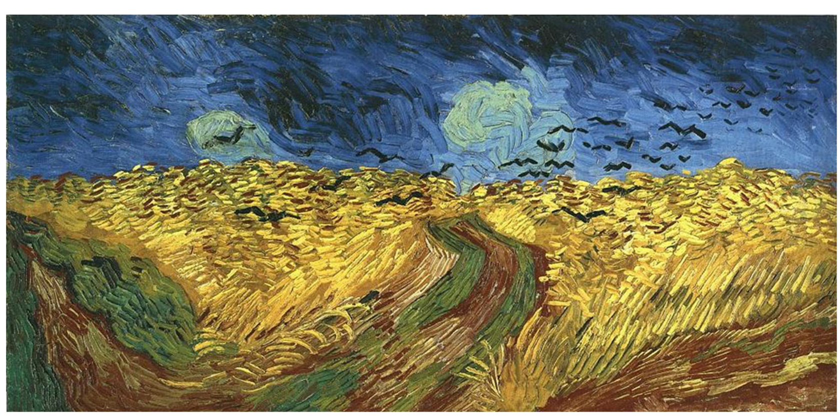

Fig. 7. Van Gogh's *Wheatfield with Crows.* Retrieved from https://en.wikipedia.org/wiki/Wheatfield_with_Crows

Fig. 8. Van Gogh's *Vase with Sunflowers.* Retrieved from:

Figure 10 shows the second nonexample, *Portrait of a Man*, by Cezanne. The painting illustrates both darkly outlined forms and energized brush strokes, but the colors are not intense in tone, missing critical feature 2. Instead, the colors are unsaturated and not distinct from each other.

Figure 11 shows the third nonexample, *The Vision After the Sermon,* by Gaugin. The colors are intense in tone and the forms are darkly outlined, but the brush strokes are clearly not energized, creating smooth color objects; thus missing critical feature 3.

The previous example highlights that one can teach concepts of all kinds, including more abstract concepts such as painting style. However, one does not need to possess a complex verbal repertoire to differential between examples and nonexamples of any concepts. For example, researchers

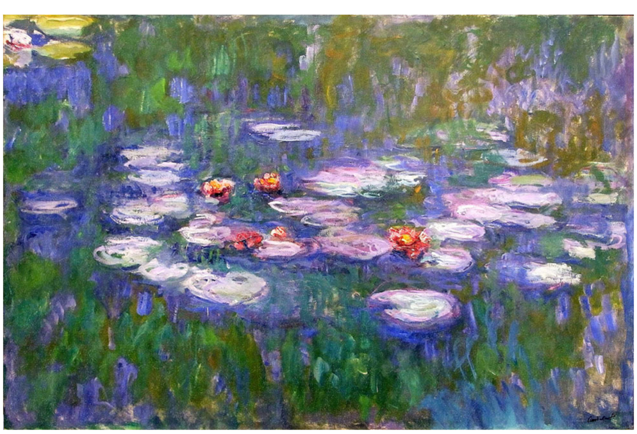

Fig. 9. Monet's *Water Lilies.* Retrieved from https://www.youtube.com/watch?v=XeApLWd7240

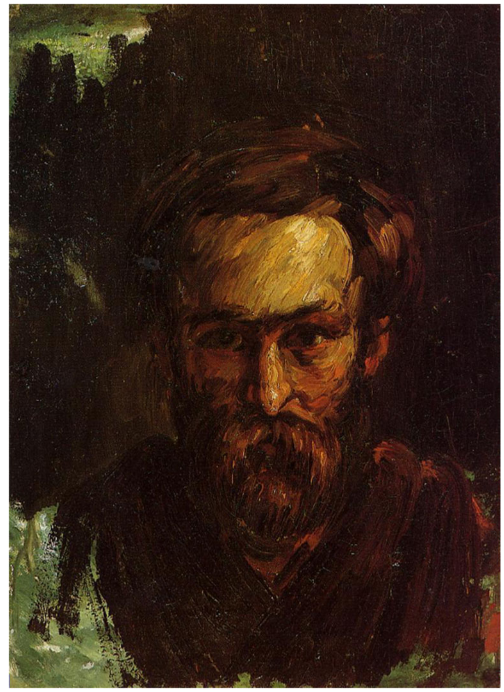

Fig. 10. Cezanne's *Portrait of a Man.* Retrieved from http://art-cezanne.com/cezanne_1860_8.html

taught pigeons to discriminate between paintings of Picasso and Monet (Watanabe et al., 1995). This brings us to an important point: the learner does not need to be able to state the critical features of the concept to correctly discriminate between examples and nonexamples. In fact, they do not need a verbal repertoire at all (Herrnstein et al., 1976; Watanabe et al., 1995).

Space does not permit us to quiz you on new examples and nonexamples, but in our last three concept workshops, over 80% of over 100 participants in each workshop correctly identified paintings by Van Gogh and discriminated them from

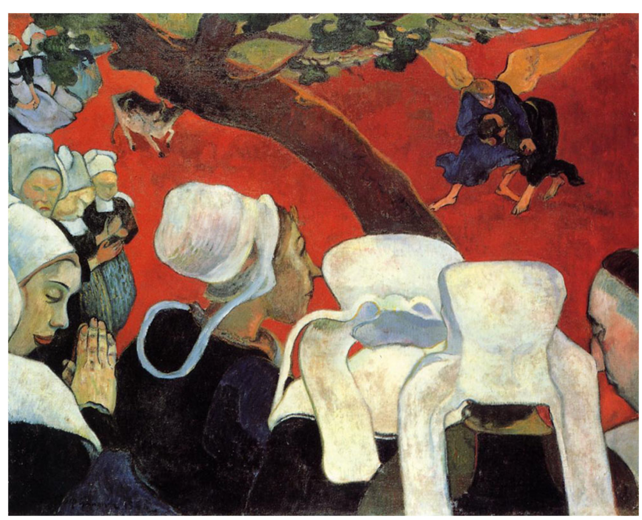

Fig. 11. Gaugin's *The Vision after the Sermon.* Retrieved from https://en.wikipedia.org/wiki/Vision_After_the_Sermon

paintings by other artists after instruction with three examples and two nonexamples for each critical feature. However, many participants need more discrimination practice to reach that goal.

Practicing and Testing for Conceptual Behavior

We need different divergent examples and close-in nonexamples from those used in instruction to both practice conceptual behavior, and test for conceptual behavior. If an instructional designer uses the same stimuli presented in instruction for subsequent practice and for later assessment, correct responses may indicate that the learner is remembering only those particular stimulus–response relations. The learner may not be able to identify the full range of stimuli that illustrate a concept, nor discard other nonexamples of the concept. For example, if the learner names the same painting presented in instruction as *impressionist*, they may be simply remembering that specific painting presented during instruction. They may not be able to identify the full range of paintings that illustrate impressionist paintings, nor all of the close-in nonexamples of impressionist paintings. Likewise, if a learner names a shape a *circle*, but it is the same size and color as one presented in instruction, they may be simply remembering that specific circle. They may not be able to identify the full range of stimuli that illustrate circles, nor all of the close-in nonexamples of circles (Johnson et al., 2020; Tiemann & Markle, 1990).

Now that we have specified all of the necessary ingredients to add to instructions for learning a concept, we are ready to assemble them in a sequence of instruction. See Twyman's article in this issue to learn how to do that.

Declarations All of the procedures in this study which involved human participants were conducted according to ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of Interest The authors declare that they have no conflict of interest.

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