How to Teach Rule Relationships, or How “Things” are Connected

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 Document 2 showed how to improve behavior. Documents 8 and 9 showed how to teach classes (triangle) and concepts (triangularity). And document 11 showed how to teach facts knowledge. This chapter shows how to teach rule relationships, or how classes are connected (Kammenui & Simmons, 1990).

What are Rule Relationships?

 Classes/concepts/names are *the kinds of things* in our human picture of reality. For instance, frogs, fish, insects, spiders, plants, water, turtles, and snakes are the *classes of things* in the class of ponds. Rule relationships tell how these classes are connected. For instance, (1) *All* (things in the class of) snakes are (in the larger class of) reptiles. (2) *Some* (things in the class of) snakes are (in the larger class of things that are) poisonous. (3) *No* (things in the class of) snakes are (in the class of things that are) lizards. These are called *category, or class, rule relationships*.

 Rule relationships also tell how classes *change together*. The more sunlight plants get (one class: causes), the more chlorophyll their leaves make (another class: effects). We call these *causal/functional rule relationships*.

 You can tell class/category rule relationships by the words “(All, Some, None) of one class is in another class.” And you can tell causal/functional rules by the words “(If, When, Whenever, The more, The less) there is change in one class, then (the more, the less) there is change in another class.”

 Knowledge (1) that there *are* rule relationships (that reality is *orderly*), and (2) that rule relationships *tell about that order* (tell how things are connected), enables us to

* *Behave effectively.* To give plants more light; to stay away from unknown snakes.
* *Explain* how and why things change. “These mountains are eroded by wind, water, and temperature changes.”
* Make *predictions.* “As the amount of sunlight decreases, leaves will make less chlorophyll and their underlying colors (yellow, brown) will be revealed.”
* *Conduct inquiry projects*. “Is there is a causal connection between the distance of planets from the Sun and their surface temperatures?”
* *Find rule relationship statements in text*, so that we know what a writer is telling. In his famous speech against ratifying the Constitution, Patrick Henry said

“(The Constitution has so many “deformities” [causes] that)

Your President may easily become king…” [effect]

“Your dearest rights may be sacrificed by … a small minority…” [effect]

 …who will “perpetrate the worst of mischiefs…” [effect]

In other words, he said more than, “I don’t like this Constitution.”

<https://theimaginativeconservative.org/2016/05/patrick-henry-constitution-speech-virginia-ratifying-convention.html>).

 Let’s first teach class/category rule relationships.

Teaching Class/Category Rule Relationships

 The method is the same for elementary and secondary students.

Teaching Elementary Students

 Here is Ms. Blue-Belle, from chapter 10.

1. Ms. Blue-Belle reviews what was taught earlier (in chapter 9) about classes.

*Gain attention.* “Everybody sitting tall ready to learn? Hands and mouths quiet; looking at Ms. Blue-Belle?”

*Yup…. Ready…. Sitting tall!*

“Great! You are such smart learners.”

*Frame instruction.*

“Let’s review our new word----class. Ready?”

*You bet….. Boy howdy!*

*1a. The Concept of Class [Writes ‘class’ on the board.]*

“There are *classes* of *things* in our room. Tell what *kinds things (classes) you see.* [Writes these on the board.]

*Tables… Books….. Walls….. Lights…. Desks…. Chairs…. Kids!*

“Let’s draw a circle around the name of each kind of thing in the room, to show that there are lots of *examples in each class*.”

“Now we’ll say the whole thing. ‘The class of’…”

[Ms. Blue-Belle points.]

*The class of tables…. The class of kids…. The class of chairs….. The class of books.*

“Yes, tables, kids, books, chairs, walls, and lights are in classes.”

*1b. Definitions and examples.*

“Look at these chairs. They are *inside* the class of chairs because they are *same* in some ways. Look at the chairs and tell the *ways* they are the same.”

*Seat…. Back…. Legs… Only one person sits on them.*

“Yes, all *examples* of chairs have a seat, a back, legs, and one person sits on them. This is the *definition* of the class of chairs.”

“But how are the chairs *different*? Look at the chairs and tell how they are different.”

*This chair has four legs… That one has curved legs… Some are blue… Some are wood and some are plastic.*

“Yes, you see how chairs are the same in some ways and not the same in other ways.”

“Listen, one chair is blue and another chair is brown. If they are different colors, or made of different materials (plastic, wood), and are still chairs, do colors and materials matter?”

*Nope… No way.. Color doesn’t matter… They are made of different materials. So, materials don’t matter, either.*

“You are so smart. All chairs have the same defining features—seat, back, one person sits---but the ways they are different---color or size or material---are not defining features,.”

[The class does the same thing with the class of tables. How they are the same---the definition. How they are different---not part of the definition.]

*1c. Some classes have more things (examples) in them than other classes.*

“Listen. Some classes have more examples in them than other classes. Here’s how we can tell. This circle is the class of things that taste good. Look inside. What kinds of food are in the class of things that taste good?”

(Students read these.)

<Insert figure 12.1 near here.>

Figure 12.1. Big Circle/Class of Things That Taste Good

 The big class of things that taste good

 The class of cookies

 The class of apples

 The class of corn bread

 The class of pancakes

 The class of pizza

“Which has more *examples* in it? The class of pizza or the *whole* class of things that taste good?”

*I dunno… Which…. I think I know!...*

“Here’s how to find out. The class of pizza *only* has pizza in it. But the class of *all* things that taste good has pizza *and* cookies *and* corn bread *and* apples *and* pancakes.”

*The class of things that taste good has more in it.*

“Yes! The class of all things that taste good has a lot *more* than just pizzas! It has more in it.”

[The class repeats the exercise---which class has more examples in it?---with the classes of corn bread, pancakes, apples, and cookies that are inside the *larger* class of food that tastes good.]

*1d. One class can be inside many other classes.*

“Listen. A thing can be in lots of classes.”

“Apples [Points to the circle.] are in the class of things that… (Test/check)

*Taste good…*

Yes, apples are in the class of things that taste good. (Verification) In what *other classes* are apples? Apples grow on…

*Trees.*

“So, apples are also in the class of things that…”

*Grow on trees.*

“What else?”

*They are food…. And red…. And green…. And you can make pies.*

“Let’s list the larger classes that the class of apples is in.”

*Food… Pies… Grow on trees…. Red, green, yellow…. Things you can pick… Things that have seeds.*

“Yes, apples are in many other classes at the same time.”

[The class repeats this exercise with puppies that are in the classes of (1) pets (along with kittens, bunnies, parrots, and baby goats); (2) things that are babies; (3) things with fur; and (4) things that you can play with.

2. Now Ms. Blue-Belle teaches new knowledge: class/category rule relationships.

Classes can be all inside, partly inside, or not inside another class. All, some, no. *Category rules tell these connections*.

“Here’s a new idea! Let’s play, Who is inside?”

*Yeh!!! Inside! Who could it be?*

<Insert Figure 13.2 near here.>

Figure 13.2. All, No, Some Class/Category Relationships

“Now we’ll learn about all, some, and no. Say those words.”

*All… Some… No..*

The class of food The class of red things The class of bananas

 cookies

 pizza peas fire trucks apples

 potatoes cheese cardinals red

 hot dogs apples cherries green

 strawberries

 apples

 apples

* Ms. Blue-Belle draws and labels the class-category circles.
* She asks students to list smaller classes that are inside the three larger classes.
* Now she asks students, “Are all apples in the larger class of food?”

*Yes.*

She moves the circle of apples inside the circle of food. She has students look at the circles and say the rule that connects apples and food…

*All apples are food.*

* She asks students if all apples are in the class of things that are red.

*No… Apples can be red… Or green… Or yellow.*

She moves the circle of apples so that part of it is inside and part outside the circle of red things. She has students look at the circles and say the rule that connects apples and red things.

*Some apples are red… Hey! Some are green!*

* She asks students if *any* apples are in the class of things that are bananas.

*No… Apples are not bananas… Bananas are bananas.*

She moves the circle of apples so that it is outside the circle of bananas. She has students look at the circles and say the rule that connects apples and bananas.

*No apples are bananas… I’d like a banana.*

* The class repeats this exercise with fish in relation to (1) things that are animals (all); (2) things with teeth (some); and (3) things that are turtles (no).
* In the future, the class diagrams and tells class rule relationships as they learn new classes/concepts/names. For example, all ponds are ecosystems, all whales are mammals, no dolphins are sharks, some snakes are poisonous.

Teaching Secondary Students

 Here is how secondary teachers might teach class/category rules.

1. Teach that *individual things are in (are examples of) classes.*

Examples might include the following.

* Familiar: Chairs, tables, lamps, cabinets, and book cases in the room are in the larger class of furniture. Each item is an example of the class.
* Forests, plains, swamps, rivers, ponds, and deserts are in the larger class of ecosystems.
* Monarchies, aristocracies, oligarchies, republics, and democracies are in the larger class of political systems.

Then have students think of examples.

2. Now show *ways that human beings organize classes*.

* Show category systems and typologies. <https://duckduckgo.com/?q=taxonomies&t=opera&iax=images&ia=images>

<https://duckduckgo.com/?q=classification+systems&t=opera&iax=images&ia=images>

* Have students construct typologies; for example, tables that list the features of: political systems; plants, animals, fungi, and protists; geological formations (mountains, plains, plateaus, river valleys); organ systems (nervous, circulatory, muscular, skeletal, gastrointestinal, skin, visual).

3. Teach that *things (examples) are seen as members of a class because their features fit the definition of the class.* For example, an ecosystem (the class/concept) is defined as the coordination of animals, plants, and microorganisms with each other and their environments. So, Hardy’s Pond—which is a coordination of animals, plants, and microorganisms with each other and their environments---is in the class of ecosystems.

4. Show that *all things called ecosystems* (deserts, rivers, swamps, forests, cities) *have these features*. But they also *vary*; they have *nondefining features*. Some deserts are hot and sandy; other desert examples are cold and snowy.

5. *Some classes contain more examples than other classes.* The class of monarchies contains only monarchies, but the class of political systems (which includes all monarchies) also includes democracies, oligarchies, republics, and aristocracies. So, the class of political systems contains more (is larger) than the class of only monarchies. Have the class think of examples of which class is larger. Continent, country, regions, states, counties, cities, neighborhoods.

6. *A class can be in several other classes*. Deserts are in the class of ecosystems. They are also in the classes of sandy places, where people live, where there is little vegetation, and where there are dunes.

7. *All, some, or no examples of a class may be in another class*. For instance,

* All monarchies are in the class of political systems. Some monarchies are governed by a wise and benevolent ruler. No monarchies govern the whole Earth.
* All deserts are in the class of ecosystems. Some deserts are in the Arctic. No deserts are completely barren of animal and plant life.

Have students think of examples.

 In the future, teachers use the above ideas with each new topic.

* What are the classes (kinds) of bacteria, muscle tissue, and organ systems?
* Which classes have more examples? Organisms or organs. Genus or species? Mountains, plains, rocks, geological formations.
* List several other classes that a class can be in. Mountains are geological formations. They are also…. Bacteria are micro-organisms. They are also….
* Make class/category rules. (All, No, Some) republics….. (All, No, Some) planets. (All, No, Some) spiders.

 Now let’s see how to teach causal/functional rule relationships.

Teaching Causal/Functional Rule Relationships

 Class/category relationships are like tiles in a mosaic that represents the chunks of our reality. The tiles aren’t moving. For instance, zoologists decided that snakes are in the larger class of reptiles, and that’s it---unless zoologists decide that snakes belong in a different class.

 In contrast, causal and functional rule relationships tell how *change in one class of things* is *connected to change in another class.* As the temperature of a bar of steel increases, the steel becomes softer. Note that we have two kinds of causal/functional rule relationships.

 *Causal rule relationships* (laws in physics, chemistry, and math) are hard connections. “(If, When, Whenever) an object is dopped off of a cliff, the object will fall faster and faster until it reaches terminal velocity. It has to. That’s the way gravity works.”

 However, *functional rule relationships* are soft. For example, as the price of a product (cars) increases, the sales of the product *may* decrease. However, higher prices are not like a natural force that *makes* sales decrease. *Some* individuals *decide* that the price is too high. The relationship between price and sales is *correlation*,but not causal.

 Causal/functional rule relationships help us to apprehend the patterns, the connections, the “ways things work,” so that we can *explain* why things happens, *predict* what will happen, and *guide* our actions.

Two Ways to Teach Causal and Functional Rule Relationships.

1. *Deductive.* Teach a when-then rule statement; have students examine examples and nonexamples, so they can see how the rule applies to the examples.

2. *Inductive.* Take students through a set of examples. Help them to identify how one set of values (for instance, how much plants grow--effect) changes along with another set of values (hours of sunlight--cause). Then teach students to state a when-then rule that summarizes the connection. “When (one thing changes)….., then (another thing changes).”

 This is the same as when we taught concepts two ways, by (1) showing examples and nonexamples, and then helping students to find the shared features that define the concept (inductive); or (2) telling a verbal definition and then examining examples and nonexamples of it (deductive).

 Let’s see how teachers do it.

Raven Redwing Teaches Younger Students About Causal/Functional Rule Relationships

*Method 1. Rule first. Then examples (Deductive)*

 Ms. R. uses this method first because it has fewer logical steps. Ms. Redwing uses a simple example. The format is described by Engelmann & Carnine (1991).

Here are the steps.

* Teach what *when-then rules* *tell about*; namely, when one kind of thing changes and then another kind of thing changes.
* Teach a specific when-then rule.
* Students examine examples to see if they fit (confirm) the when-then rule.

Let’s read aloud along with Ms. Redwing. Students’ talk is in italics.

*Gain attention.* “Boys and girls. Ready to learn? Sitting calm. Nice and quiet. Looking at Ms. Redwing….We’re going to learn about when-then rules. [Writes “when-then rules” on the board.] When-then rules tell what happens *when*. *When* you go outside in the rain, *then you get*…”

*Wet… soaked… soggy… chilly… a cold….*

“Here’s another when-then rule.”

“*When* the Sun goes down in the evening, *then* it gets…”

*Cold…dark…spooky…time to come inside…*

“Yes, those when-then rules tell that *when* the Sun goes down, *then* something happens.”

[Now the class examines examples that show, or conform to, the when-then rule. The authors are indebted to Engelmann and Carnine (1991) for the example formats.]

*Model.* “Boys and girls, here’s a when-then rule. *When* we go from one line to the next line, *then* the lines get longer.” [Ms. Redwing writes the rule on the board.]
*Test/check.* “What’s our when-then rule?”

*When we go from one line to the next line, then the lines get longer.*

“Yup, when we go from one line to the next line, then the lines get longer.

*Generalization Test/check.* “So, if we look at a row of lines, what will the lines get as we go *along* the row, this way 🡪?”

*Longer.*
“Let’s see if examples *follow* that rule—that the lines get longer. Follow my finger!

<Figure 13.3 near here.>

Figure 13.3. Lines Get Longer.

Ms. Redwing helps students to go through the line-examples one by one, and to check if the lines do get longer.

 First Now go to Now go to Now go to Now go to So, what happens
 line the next line. the next line. the next line. the next line. to the lines? What
 What happened? What happened? What happened? What happened? is the rule about *It got longer. It got longer. It got longer. It got longer.* lines? *The lines*

 *get longer.*

*Generalization Test/check.* “Let’s use our when-then rule…. What will happen to the *next* line?”

*It will get longer.*

“How do you know?” [Students use the rule to explain their answer.]

*The rule says so… The lines always get longer… So, the next line will be longer.*

“Excellent *prediction*---telling what will happen (synonym) from our when-then rule.”

 Ms. Redwing invents more opportunities for students to use method 1 when they are learning science, history, health, and other subjects. For instance,

“Here’s a when-then rule about health. *When* you turn off your computers and cell phones an hour before you go to sleep, *then* you will fall asleep faster. Let’s do an experiment and test the rule.”

\* \* \* \* \*

 Now Ms. Redwing teaches students method 2: how to figure out (construct) a when-then rule *from* a series of examples. This requires that students do more steps. That is why Ms. R. began with (the easier) method 1.

*Method 2. Take Students Through Examples and Help Them to Figure Out (Construct) the When-then Rule (Inductive)*

 Let’s follow along with the class.

*Gain attention.* “Now my smartie students, do you want to be even smarter?”

*Yup… Sure do…Boy, howdy!... I’m pretty smart already.*

“So, let’s sit in our ready-to-learn positions….”

*Frame.* “When we did lines, I *told* you the when-then rule. Then we looked at examples one after another, and you could *see* how the lines got longer, just as the when-then rule said. [Ms. R. points to the example of lines.]

“*Now*, we’ll look at *examples*, and we’ll *figure out* the when-then rule about *how* the examples change *together* we go from one to the next.”

“Listen. Here’s how you make a hard-boiled egg. You put a pot of water on the stove; you turn on the heat; the water boils; and you put the egg in. Then you wait a few minutes; you take the egg out; you crack it open; and you eat it.” [Ms. R. writes the steps on the board.]

“Here are examples of making boiled eggs. Look at each example on the table.”

<Table 13.1 near here.>

Table 13.1. Eggs.

 When egg was in boiling Then egg got this hard

 water for

Example 1 0 (no) minutes Not hard at all. Runny. Yuck.

Example 2 1 minute A little hard.

Example 3 3 minutes Pretty hard

Example 4 5 minutes Very hard

“So, first let’s look at the *when* part to see how many minutes the eggs are in boiling water.”

*0 minutes in boiling water, 1 minute, 2 minutes, 3 minutes.*

“So, how do the minutes change from example 1 to example 4?”

*More minutes… Longer.*

“Correct! [Ms. Redwing points to each example.]

“Now let’s look at the *then* *changes* in how hard the eggs get. How do the eggs change as we go from Example 1--0 minutes; to example 2--1 minute; to example 3--3 minutes; and example 4--5 minutes?” [Ms. Redwing points to each example.] “Do the eggs get harder when they are boiled for more minutes?”

*Yes.*

“Let’s see if we can figure out the when-then rule about boiled eggs. I’ll help.”

“When eggs are in boiling water for *more* minutes, *then*…” [She goes down the examples in the *then* column.]

*They get harder.*

“Okay, class, now *you* say the when-then rule about boiled eggs all by yourself. Say the *whole* rule.”

*When eggs are in boiling water for more minutes, then they get harder.*

“Perfect. You figured it out and you told the rule.”

*Generalization Test/check.* “Let me ask you a question. The when-then rule is, ‘When eggs are in boiling water for more minutes, then they get harder*.*’ So, what will happen if eggs are in boiling water for 7 minutes!?”

*Then they get harder… Like rocks…*

“How do you know?” [To help students use the rule to make predictions, or deductions, from the rule.]

*The rule says so… When eggs are in boiling water for more minutes, then they get harder....*

*A 7-minute egg is in longer than a 5-minute egg, so it will be harder than a 5-minute egg.*

Gee, you guys are scientists!!

\* \* \* \* \*

 Ms. Redwing’s students are going to be smart! She will teach students to see how examples fit when-then rules (method 1), and also how to construct when-then rules to fit examples (method 2). Like these…

* When months of the year change (from December through June), then the hours of daylight change (from… hours a day to…. hours a day).
* When there is more sunlight (days are longer) in spring and summer, then (what happens to plants, the temperature outside)?
* When certain things happen in a story, then other things happen next.
* When the slope on a mountain is steep, and the snow piles up high, then the snow will …. (avalanche).

Mr. Knight Templar Teaches Older Students About Causal/Functional (When-then) Rule Relationships

 Mr. Templar teaches when-then causal/functional rules both ways:

1. Method 1. Teach the rule; then show (or students find) a series of examples; help students to tell if the rule summarizes how the examples *co-vary* (change together).

2. Method 2. Show (or students find) a series of examples; then help students to compare and contrast examples and to construct (figure out) a rule that summarizes how the examples co-vary (change together).
 Here is Mr. Templar’s format. Please read aloud with the class. Use your own wording when you teach, but it’s wise to follow the logical sequence. Mr. Templar first introduces the topic. Let’s speak along with Mr. T. and the class.

*Gain Attention and Frame Instruction.* “Now, my excellent students, get ready to become real smart. Eyes on me, and prepare to take awesome notes….. I love how you got ready so fast.”

*Frame.* “We’ve learned a lot of *concepts* and *facts* about our solar system. We learned the concepts of solar system, planet, orbit, comet, and gravity. And we’ve learned *facts*, such as Mercury is the planet closest to the Sun, and the circumference of the Earth is 24,900 miles.”

“Now we’ll learn how parts of the solar system go together, *how they change together*. *Rule relationships* tell these connections, or goings-together.”

“Here’s an example of a when-then rule relationship. When the pressure applied to gas in an enclosed space (such as gasoline vapor in a car cylinder) increases (higher pressure), the temperature of the gas increases. So, what will happen if you increase the temperature of the gas in an enclosed space?”

*It will increase.*

“What could you do if you wanted the gas in the cylinder to increase?”

*Increase the pressure.*

“Correct!”

“So, we can use that when-then rule relationship to *predict* what will happen, and we can use it to *guide* our actions. ‘Don’t increase the pressure any more! The gas will explode!’”

*Review and Firm Earlier Knowledge.* “Take out your (Cornell Notes, Guided Notes) on our last three lessons, and let’s review. What did we learn? Skim your notes…. Now, I’ll say part of a sentence, and you tell the rest.”

“We assume that the solar system is…..”

*Orderly.*

“Yes, it *is* orderly. Let’s see how…”

“Each planet spins its way around the Sun in its…”

*Orbit…. It’s own orbit.*

“Each planet maintains much the same speed of ....”

*Rotation… Rotation on its axis…*

“And each planet maintains the same time it takes to…”

*Complete its revolution around the Sun*…. *Orbit…*

“Each planet is sustained in its orbit by the balance of two forces---first, the Sun’s…”

*Gravity…*

“What does gravity do?”

*Pulls the planets in… Sucks ‘em right in…”*

“At the same time, a second force pushes the planets *out*… What force?”

*Centrifugal force*… *Pushes ‘em out.*

“Yup, you got them all right. Good using your notes!”

*Introduce New Idea: Orderly Change.* “Think about this…. *Everything changes every second.* Clouds move. The Earth turns. Plants grow. Mountains erode. Water runs downstream. Cells in our bodies multiply.”

[Mr. Templar writes on the board.]

“Everything is changing every second.”

“However, some changes are *orderly*!”

“They aren’t random. Things change together! They are connected. There are patterns.”

“We can find these patterns—the connections.”

“And then we can *tell* these connections with when-then rule statements. For example, *When* the Earth’s tilt brings a hemisphere closer to the Sun as the Earth moves in its orbit, *then* days get longer,and the temperature of that hemisphere increases.”

*Investigation of the New Idea of When-Then Rule Relationships.* “Now we’re going to figure out a when-then rule relationship. And we’ll use them to make predictions. But first, let’s review.”

Mr. Templar shows visuals of the solar system that students have seen before. The class reviews concepts and facts---solar system, Sun, planets, moon, gravity, density, centrifugal force, rotation, revolution, asteroid, comet. He begins with method 1.

*Method 1. Rule first. Then examples (Deductive)*

<Table 13.2 near here.>

Table 13.2. Facts About Approximate Distances of Planets from the Sun, and Their Orbits.

[m = million. b = billion]

 Column 1 Column 2 Column 3 Column 4

 Planet Distance from Miles of orbit Time of orbit

 Sun in Earth years

 Mercury 37 m 224 m 3 months
 Venus 67 m 423 m 7 months
 Earth 93 m 584 m 1 year
 Mars 142 m 888 m 2 years
 Jupiter 484 m 4 b 12 years
 Saturn 887 m 6 b 30 years
 Uranus 1.8 b 11 b 84 years
 Neptune 2.8 b 17 b 165 years
 Pluto 3.7 b 23 b 248 years

*Frame. “*Look at the three columns on our table…. We have three *variables* that describe the planets. The table tells *facts*---the *values* of each variable for a planet.”

*Instruction.*

“Column 2. What values does it show…”

*How far each planet is from the Sun, in millions of miles.*

“Column 3. What values does it show?…”
*The size of each planet’s orbit around the Sun, in millions or billions of miles.*

“Column 4. What values does it show?…”

*The amount of time it takes for each planet to travel around the Sun—its orbit—in Earth months and years.*

*Model.* “Here’s a rule that connects the values in Column 2 with the values in Column 3. Listen… The farther a planet is *from* the Sun, in miles, the longer in miles is its orbit *around* the Sun.” [repeat?]

*Test/check.* “What’s our when-then rule?”

*The farther a planet in miles is from the Sun, the longer in miles is its orbit around the Sun.* [Mr. Templar corrects errors by modeling the rule again, and retesting.]

[If students already know geometry, Mr. Templar shows why there is a relationship between distance from the Sun and distance around the Sun.]

“But *why* is there are relationship between a planet’s distance from the Sun, and the distance it travels to orbit around the Sun?”

*I forgot… Me, too…*

[Background knowledge used to answer the question.]

<Figure 13.4 near here.>

 Figure 13.4. Solar system.

 Sun

 Radius Mercury

 Venus

 Earth Circumference, orbit

“Let’s use something you learned in geometry. Look at the diagram on the board. Find the radius of a planet from the Sun (its distance from the Sun) and its corresponding circumference (orbit).”

“So, how do you find the circumference—the distance around, the orbit?”

“The equation is C = 2 x pi (3.14) x radius.”

“The radius is a planet’s distance from the Sun.”

“Pi is 3.14.”

“So, if the radius (distance of the Earth from the Sun, which is in the center of the almost circular orbit) is 93 million miles; and we multiply 3.14 by 2 (6.28) and then by 93 million, we get the circumference---Earth’s orbit. Do the math!”

*584 million!*

“Yup! That is Earth’s orbit.”

[Now that the class has learned the rule, students examine (compare and contrast) examples of it.]

“Look at our table. As the planets are farther *from* the Sun in miles (column 2), do they have to go farther in miles to *get around* the Sun in their *orbits* (column 3)?” [Note repeated use of “farther.”]

“Let’s do all of our planet examples to see.”

“Start with Mercury. Let’s find out how far it is from the Sun---column 2. Then we’ll look at column 3, to find out the size of its orbit.”

[The class does this for each planet. Mr. Templar has students see and tell that *the next planet farther from the Sun has an even larger orbit around the Sun than the closer planets.*]”

“So, do the facts fit the rule?”

*Yup… They sure do.*

“So, we can say that the rule accurately tells the connection between distanced from the Sun and distance around the Sun.”

*Test/check.* *Follow-up questions that require students to use the rule to explain.*
“Why is Jupiter’s orbit around the Sun larger than Earth’s orbit around the Sun?”

*Because Jupiter is farther from the Sun than the Earth is.*“Yes! You used the rule!”

*Generalization.* *Mr. Templar now teaches students to use the rule to make predictions.*
“Let’s say that there is a planet even farther from the Sun than Pluto. Would its orbit around the Sun be longer or shorter than Pluto’s orbit?”

*Longer!*

“How do you know?”

*Because it’s farther away.*

[Mr. Templar corrects errors by telling the rule and then showing that when the distance is farther from the Sun, the orbit is longer. Then he repeats the question--retests!]

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Now Mr. Templar and the class use method 2.

*Method 2. Take Students Through Examples and Help Them to Figure Out (Construct) the Rule (Inductive)*

 The class examines the set of planet fact-examples, and figures out (constructs) a rule that summarizes any connection (regularities) between change in one variable and change in another variable.

Mr. Templar begins…. *Frame.* “My excellent class, listen.”

“In the first method, we started with a when-then rule that we already knew---that, when the distance of planets from the Sun increases, then the length of their orbits in miles also increases. Then we looked at the data (the facts on distance from the Sun and the length of orbits---columns 2 and 3) to see if the data fit the rule and if the rule fits the data.”
“Did the rule fit or summarize the data?”

*Yup… sure did.*

“This means that we *can use the rule to make predictions*. Given a planet’s distance from the Sun, we can predict whether its orbit would be larger or smaller than the orbits of other planets.

Now we’re going to do more than just see *if* examples are summarized by a rule statement.”

*What?... This is getting mysterious!... What will we do?... Please tell us.*

“Okay.”

*Frame instruction.*

“1. This time, we will not start with a rule. We will figure it out, or construct it, from the data-examples. How?”

“2. We will compare examples one by one. The data on Mercury; then Venus; then Earth; and so on.”

“3. Then we will see if the data show that, when one variable (one set of facts on the planets) changes, then does the other variable (a second set of facts on the planets) also change *in a regular---not random---way.*”

“4. Then, we will think of a rule statement that summarizes any regular changes from planet to planet.”

“Here’s how we will do it.”

“We are going to see if there is a relationship between changes in the distances of planets from the Sun (column 2) and the time it takes for planets to orbit the Sun (column 4).“Let’s compare and contrast examples.”

*Lead and Test/check.* “Let’s start with Mercury again.”

“How far is it from the Sun? Column 2.”

*37 million miles.*

“Now look at column 4. How long does it take for Mercury to orbit the Sun?”

*3 months… Pretty fast… Well, yeah! It’s so close!*

“Good thinking, Mitch.”

“Now do Venus. What are its facts?”

*67 million miles from the Sun and an orbit of 7 months.*

*Test/check.* “Is Venus farther from the Sun than Mercury?”

*Yup. Sure is…*

“And does it take longer for Venus to make its orbit?”

*Yup again.*

“So, maybe, *when* a planet’s distance from the Sun increases, *then* the time it takes for the planet to orbit the Sun also…..”

*Increases!!*

“Very smart. You are starting to see a when-then rule relationship.”

“Keep going. What are the facts about Earth?”

*93 million miles from the Sun, and an orbit that takes 12 months.*

“Is that consistent with the data on Mercury and Venus? Farther distance from the Sun goes with longer time to orbit the Sun?”

*Yes… Looks like we discovered another rule.*

“Maybe. But keep going. Maybe the relationship between distance from and time around the Sun will become *random*.”

“So, look at the data on in columns 2 and 4 for the rest of the planets.”

“Is it still the case that when distance from the Sun increases, then the time around the Sun also increases?”

*Yes.*

*Test/check.* “So, are you ready to state the relationship as a when-then rule?”

*Yup!*

“Then tell it!”

*When planets are more distant from the Sun, then it takes longer for planets to orbit the Sun.*

“Excellent logic!”

*Generalization from the rule.* “What if they discover a planet called Poseidon, and it is even closer to the Sun than Mercury…”

*Hey, that’s some hot planet, boy howdy… Toasty.*

“Yes, toasty.”

“What can you say about the time it takes Poseidon to orbit the Sun?”

*Less time than it takes Mercury…. Fastest orbit of all.*

“Tell the rule that explains why? What is your deductive reasoning?”

*When planets are more distant from the Sun, then it takes longer for planets to orbit the Sun.*

*Poseidon is closer to the Sun than Mercury. Fact.*

*So, its orbit will take less time than Mercury. Conclusion.*

“You guys are the best!”

 \* \* \* \*

*Your turn.*

1. Find a data set on something you’d like to teach to older students. For example, years of schooling in relation to annual income. Age in relation to the likelihood of having a heart attack. How far planets are from the Sun and the surface temperatures of planets.
2. Prepare a simple table that lists the values of each variable.
3. Use method 1. Tell students the when-then rule that connects that two sets of variables, and then take them through the data to see how the rule summarizes the facts.
4. Then use method 2. Have students examine the data. When the value of one variable changes (for example, persons get older), then what happens to the other variable (for example, the chances of a heart attack)? Then have students summarize any regularities with a when-then rule statement. “As persons get older, the probability of heart attack…”

Okay, in the next chapter, we learn how to teach the fifth kind of knowledge---routines. Then we will use all five kinds of knowledge in 5-Part Lessons.

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References

Engelmann, S., & Carnine, D. (1991). *Theory of instruction.* ADI Press.