Analogies and the 5E Model

Suggestions for using analogies in each phase of the 5E model

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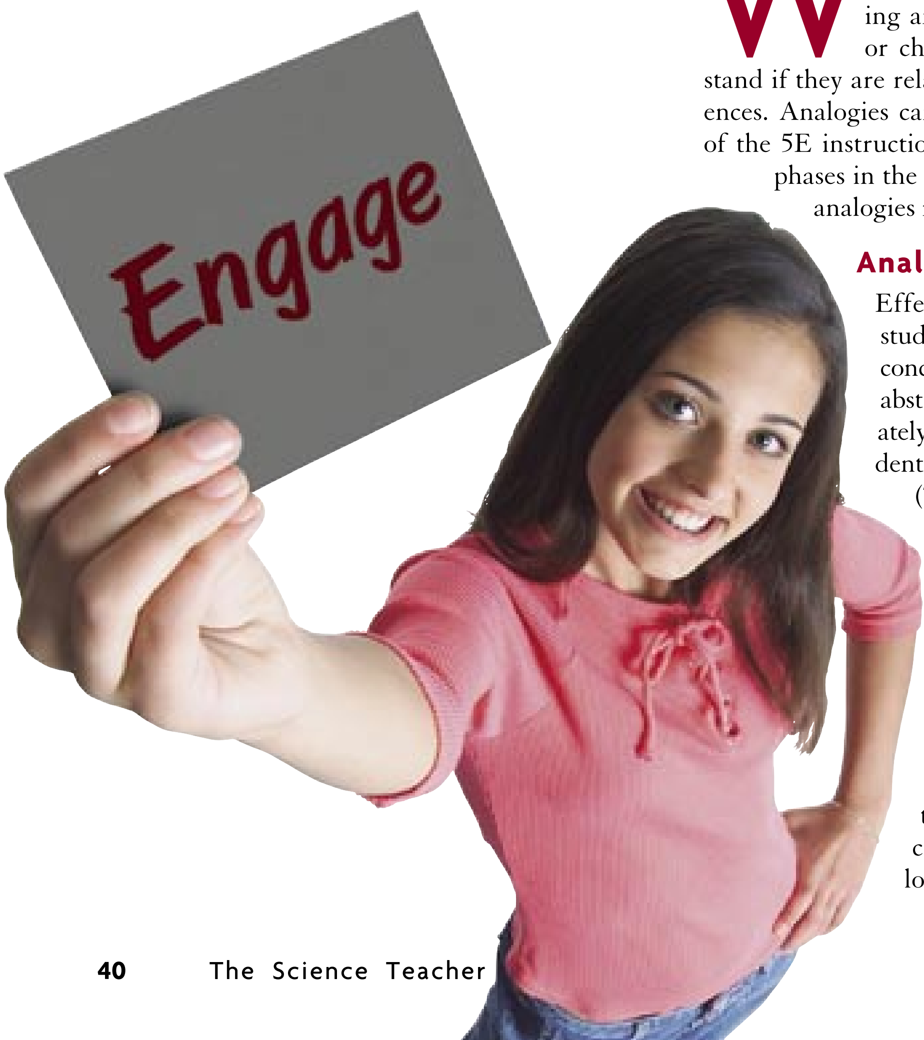
We have all sat in classes in which a teacher made a difficult or abstract concept understandable by using an analogy. Science classes are full of abstract or challenging concepts that are easier to understand if they are related to something from our everyday experiences. Analogies can be useful instructional tools in each phase of the 5E instructional model. This article briefly describes the phases in the 5E model and provides suggestions for using analogies in each phase.



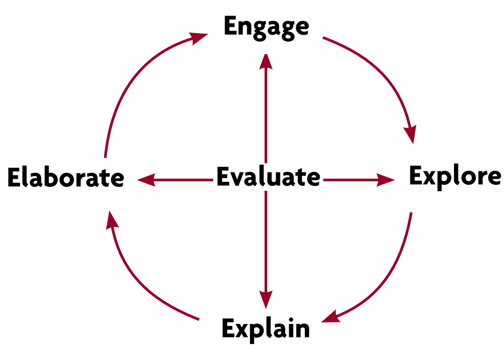
Analogies and inquiry

Effective analogies motivate students, clarify students' thinking, help students overcome misconceptions, and give students ways to visualize abstract concepts. When they are used appropriately (Glynn 1995), analogies can also promote students' meaningful learning and conceptual growth (Treagust, Harrison, and Venville 1996).

Simply put, analogies compare two concepts or ideas—one that is familiar and one that is less familiar. The familiar concept is often referred to as the *analog;* the less familiar concept, or the concept to be learned, is usually referred to as the *target.* For example, in many biology textbooks, the enzyme/substrate interaction is compared to placing a key in a lock, where the enzyme/substrate interaction is the target concept and the placement of the key in the lock is the analog concept. Because analogies

FIGURE 1

Phases of the 5E model.



use familiar information to explain unfamiliar information, they are useful constructivist teaching strategies (Harrison and Treagust 1993).

According to constructivist learning theory, knowledge is constructed as students integrate new information with their pre-existing knowledge base (Bodner 1986). Proponents of constructivism suggest that students learn science best when they are actively engaged in doing science or in performing activities that allow them to think like scientists. As such, a major emphasis in science curricular reform is a change from a more traditional teacher-based learning to a more inquiry-based, student-centered learning (NRC 1996).

The 5E instructional model (Bybee 1993) is designed to incorporate all aspects of inquiry learning environments by *engaging* students and allowing students to *explore* the concepts being introduced, discover *explanations* for the concepts they are learning, and *elaborate* on what they have learned by applying their knowledge to new situations. Throughout the process the model offers multiple opportunities for *evaluation* of students' understanding (Figure 1).

In the following sections, we briefly describe the phases in the 5E model and give suggestions about how to use analogies in each phase. We use analogies from biology and chemistry classes to illustrate our points.

Engage

The goal of the first phase of the 5E model is to give students an opportunity to become motivated or excited about the information they will learn. Engagement is designed to tap into students' previous knowledge and identify misconceptions before proceeding with the learning process (Trowbridge, Bybee, and Powell 2004). Typically, this is done with activities, demonstrations, or stories that grab students' attention and help them make connections between the new information and the world they know. Analogies are uniquely suited to the goal of this phase. Lemke (1990) says that students are more likely to pay attention to the familiar language used in analogies than to unfamiliar, more "scientific" terminology.

Analogies in the engage phase are usually provided by teachers. For example, one of our colleagues uses a visual analogy to explain compounds and mixtures to his chemistry students. He brings a box of Raisin Bran and a box of Crispix with him to class, and his students pay attention because they want to know why he has cereal in class. The teacher compares mixtures to Raisin Bran because it contains two separate components (raisins and flakes) just as chemical mixtures contain two or more components combined physically, but not chemically. He compares compounds to Crispix cereal because each time he reaches into the Crispix box, he pulls out the same pieces: "bonded" squares made of rice on one side and corn on the other. The composition of the square is constant, consisting of half rice and half corn, bonded together, just as each molecule of a given compound is composed of the same number of atoms bonded together in the same way.

The key point to this story is that the teacher used an analogy that was out-of-the-ordinary to introduce a new concept. To engage students, an analogy should be novel (e.g., a song, a poem, or a story), visual (e.g., a demonstration or visual aid), or directly related to students' everyday experiences.

Explore

In the exploration phase, students interact directly with the material, concepts, or phenomenon. Usually, the teacher provides a focused activity to direct students' interactions. The teacher, although intricately involved in the process, acts as a facilitator rather than giving direct instruction to students (Bybee 1993).

Analogies can provide the focus for an exploration activity. Consider this example for a chemistry lesson. "Some people say that an atom is like a bookcase. In what ways is an atom like a bookcase? In what ways is an atom *not* like a bookcase? Be sure to back up claims with pictures, textbooks, web pages, or content you have covered in other classes." Students should be told to examine both the similarities and the differences between analog and target. Students need to understand that no analog is completely like the target concept it describes if they are to learn effectively from analogies.

Students can also be assigned analogy positions to defend—"an atom *is* like a bookcase" or "an atom *is not* like a bookcase." The process of debating the analogy forces students to look at the concepts from different perspectives (Orgill and Bodner 2004). Debate also allows the class to develop concrete ideas about the target concept that are meaningful to the group as a whole and that can be used for discussion during future phases of the 5E model. Additional explore activities are found in Figure 2.

Explain

Most teachers recognize the explain phase as "lecturing" or interactive discussion, where teachers give students information they may not be able to glean on their own. At this point in the 5E model, teachers help students understand scientific explanations and introduce terminology to provide students with a common language about the content (Bybee 1993). Many scientific explanations are not intuitive, particularly to students who are encountering concepts for the first time. Analogies can make new concepts easier to understand, easier to visualize, easier to remember, and more plausible in the minds of students (Orgill and Bodner 2004). Analogies can also introduce students to unfamiliar scientific language by giving them a concrete reference for the new vocabulary (Lemke 1990).

In order to effectively use analogies to explain scientific concepts, teachers should explicitly identify both the similarities and the differences between analog and target concepts (Treagust 1993). If a teacher only says that "a chemical equation is like a recipe" (Figure 3), students may not understand how the two concepts are similar and how the two concepts are different. As a

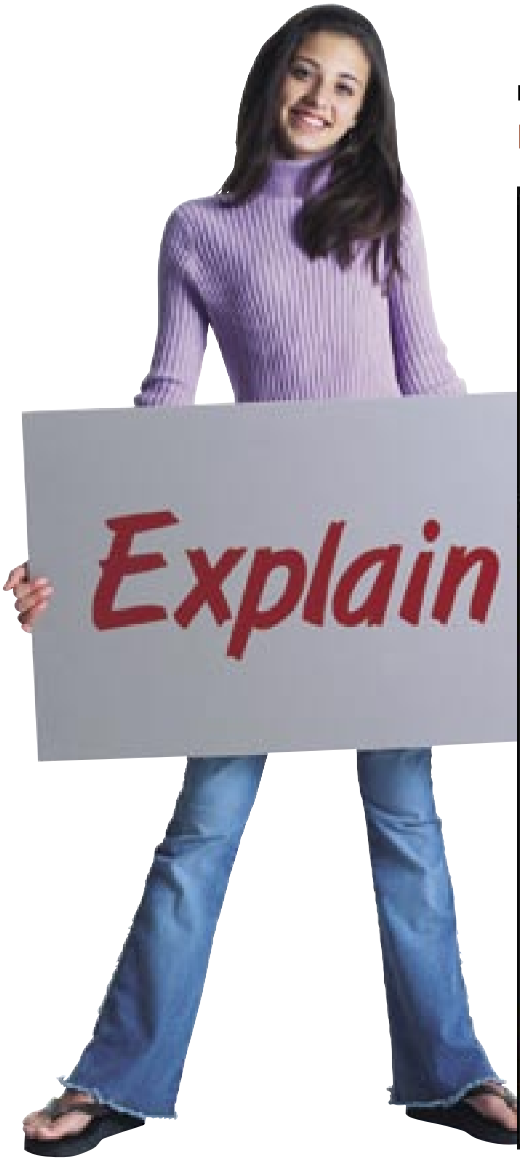
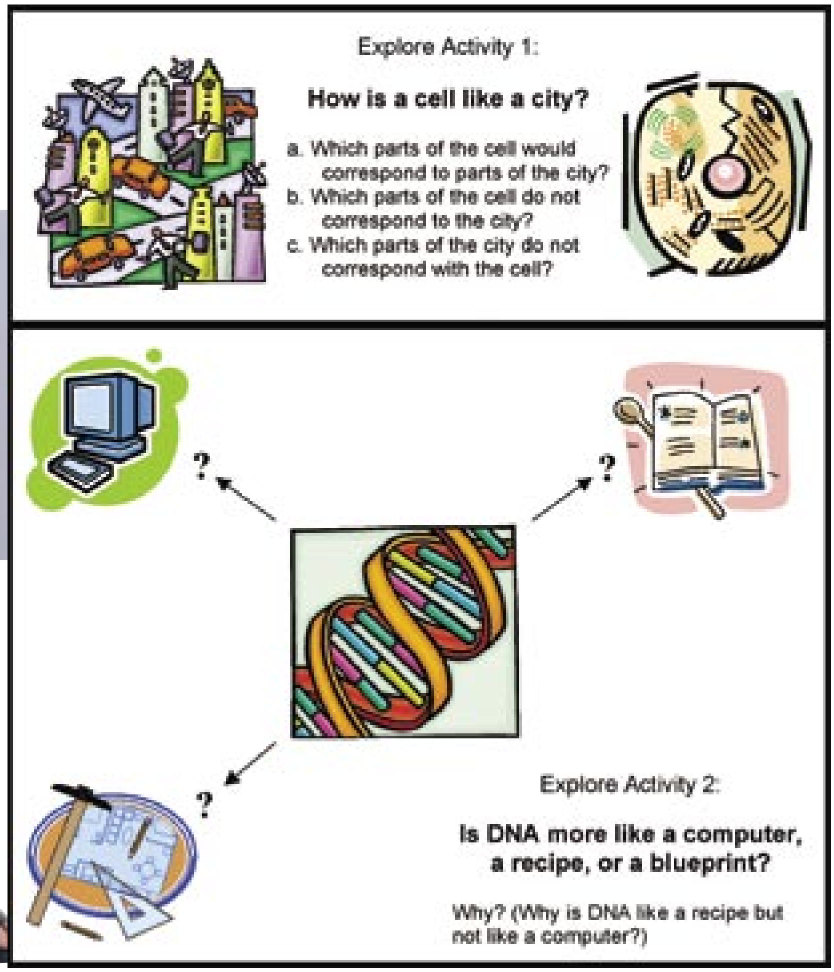


FIGURE 2

Example explore activities.



consequence, students may make incorrect inferences based on the analogy (Glynn 1995). This is particularly true for analogies that do not involve visual aids (Orgill and Bodner 2004). Identifying similarities between the two concepts has an additional benefit: It allows teachers to highlight the features of the new material they want students to learn.

Once teachers explain the analogy, they need to check students' understanding of the analogy through questioning or short writing assignments. For example, "Why did I say that the families in the periodic table are like human families?" This allows the teacher to know whether students understand the analogy in the way the teacher intended (Treagust 1993).

Elaborate

The elaboration phase of the 5E model allows students to apply knowledge they have gained to new situations

FIGURE 3

"A chemical equation is like a recipe" analogy.

Brigadeiros (Brazilian Chocolate Candy)

Ingredients:

1 can sweetened condensed milk

1 cup powdered chocolate milk mix

1 grated milk chocolate bar

Directions:

Empty condensed milk into a pan; add powdered chocolate milk mix. Stir the mixture with a wooden spoon until it is gooey and not watery. Make sure to have the stove on low heat and keep stirring constantly. Let cool for 20 minutes. Grease hands with butter or margarine. Using a teaspoonful of the mixture, roll chocolate mixture into a ball and then roll ball into grated chocolate. Let cool. Can be frozen or refrigerated. Makes approximately 2 dozen.

The Thermite Reaction

$$2Al(s) + Fe_2O_3(s) \xrightarrow{\text{glycerin}} Al_2O_3(l) + 2Fe(l)$$

How are chemical equations like and unlike recipes?

1. Recipes have names. Many (but not all) reactions have names.
2. Recipes have a list of ingredients. Chemical equations list reactants (Al and Fe_2O_3).
3. Recipes list the amount of each ingredient required. The coefficients of a balanced chemical equation tell us the amounts of reactants required for the reaction to occur. [Note: Technically, the coefficients give the molar ratios of reactants needed.]
4. Most recipes list the state of the ingredients. In this example, the chocolate must be "grated," not "whole" or "melted." Chemical equations contain information about the state of the reactants. In the thermite reaction, solid aluminum reacts with solid iron (III) oxide. [Note: Although chemical equations also list the states of the products, most recipes do not list the states of the products.]
5. In a recipe, a product is made (e.g., brigadeiros). Chemical equations list products that are made (Al_2O_3 and Fe).
6. Recipes usually tell us how many products should be made when we use the ingredients listed—"approximately 2 dozen candies." The coefficients in balanced chemical equations also tell us how many products should be made when we use the amounts of the reactants listed—"when 2 moles of aluminum react with 1 mole of iron (III) oxide, 1 mole of aluminum oxide and 2 moles of iron are produced."
7. Recipes list the conditions for making food (e.g., low heat). Some chemical equations list conditions necessary for a reaction to occur (e.g., Is heat required? Is a catalyst required? Will the reaction occur in water?). These conditions are usually written above the reaction arrow (e.g., reaction occurs in the presence of a "glycerin" catalyst).
8. Although most recipes give directions for how to make a certain food, most chemical equations do not give directions for how to carry out a particular reaction.
9. This recipe provides directions for how to store products. Chemical equations do not provide this information.

so they can expand their understanding (Bybee 1993). In this phase, students might be asked to create their own analogy for a concept. Such analogies can provide teachers with a great deal of information about their students' understandings of the target concepts. In an example from a biology class, students were asked to apply their knowledge of cellular organelles by creating a travel brochure for the organelle of their choice. While the description could be fictitious with regards to the trip, the information about their organelle needed to be based on reality. Students were assessed both on their content knowledge and their ability to explain why their analogy was appropriate.

For instance, one student designed a travel brochure for a cruise that traveled the "seas of the cytoplasm," during which the travelers could see the mysterious mitochondria volcanoes (the energy-making mechanisms), view proteins being made in the ribosomes, and spend a day sunning themselves on the chloroplast islands. This student's idea of the cytoplasm as a sea, while not exactly correct, encompassed the idea that the cytoplasm is a water-based medium that bathes cell organelles. The creation of the travel brochure allowed the student to construct knowledge of cellular structures in relation to concepts already understood—oceans and islands.

Evaluate

Although we are presenting "evaluation" as the final stage of the 5E model, it can and should occur at each stage of the instructional unit. Evaluation of student understanding need not be formal. It can be a quick question from the teacher as students exit the class or it can be a unit test and summative assessment on specific information. The information following provides suggestions for evaluating students' analogical understanding in each of the phases of the 5E instructional model.

Engage

Teachers could ask students to respond to an analogy in student journals. "I have told you that mixtures are like Raisin Bran and compounds are like Crispix. What questions do you have now about compounds and mixtures?" Alternatively, students could explain the teacher's analogy in their own words in their journals. The information from student journals can provide a focus for future learning.

Explore

During exploration activities, students examine similarities and differences between analog and target concepts. Their explanations and debates allow teachers insight

Lock-and-key analogy for enzyme action.

How is the lock-and-key model a good analogy for enzyme action?	How is the lock-and-key model not a good analogy for enzyme action?
◆ Like most locks and keys, most enzymes are specific to one substrate. In most cases, one key fits one specific lock. ◆ The lock (enzyme) has an "active site" where the key (substrate) fits. ◆ The lock (enzyme) can be used over and over again. ◆ The lock (enzyme) is generally larger than the key (substrate).	◆ Unlike enzymes and substrates, the lock and key do not change with temperature, pH, or other environmental factors. ◆ The key does not change when opening the lock, but the substrate does change (react) when acted upon by the enzyme. ◆ Unlike a lock and key, enzymes and substrates often change shape when they bind to each other. ◆ Unlike locks, enzymes often require cofactors, coenzymes and effectors to function. Enzyme activity also can be decreased by inhibitors.

FIGURE 4

General rubric for analogies.

		Points possible	Points awarded
1	Does the student provide an analogy? ◆ Does the analog sufficiently illustrate the target?		
2	Do the similarities between analog and target make sense? ◆ Does the student explain the similarities?		
3	Is the analogy scientifically correct? ◆ Does it make sense? ◆ Does the analogy take scientific fact into account?		
4	Does the student illustrate how the analog and the target are different? ◆ Does the student explain WHY the analog and target are different?		
	Total Points		

into specific misconceptions their students hold. Teachers can then adjust their subsequent instruction to address students' misconceptions.

Explain

When using analogies to explain science concepts, teachers should ask students to explain an analogy in their own words or to identify the specific mappings or limitations of the analogy. Students' explanations highlight what they have and have not learned from the analogy. For example, students can be asked: "How is the lock-and-key model a good analogy for enzyme action? In what ways is it *not* a good analogy (see "Lock-and-key analogy for enzyme action")?"

Elaborate

Teachers can use the analogies their students create in this phase to determine students' current understandings of the concepts. We have included a sample rubric for evaluating student-generated analogies (Figure 4). This rubric is designed to be given to students before they create their analogies to aid students in the development of a rich analogy.

Analogies in your class

Analogies play a significant role in human problem-solving, communication, and creativity. An analogy's potential to make explanations of new material intelligible to students makes it a powerful tool for educational purposes. Try using creative analogies in your classroom, and see what they can do for your students' understanding. ■

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