Sample Instructional Sequence: Photosynthesis

The Ruby Realm is a digital game that addresses common misconceptions about photosynthesis, such as that plants grow by transforming soil into solid material—e.g., stems and branches. The game can help students visualize a number of difficult concepts related to photosynthesis.

This instructional sequence provides: resources to help you link the game to your teaching unit; a PowerPoint presentation; several linking activities; discussion questions; and "quick writes." It also indicates optimal times for you to make links between the game and the content of your lessons.

Gameplay: Introductory Exploration

Give students ample time to explore the game before you begin your instructional unit. Pre-assign the game as homework for two days before you begin your photosynthesis instruction. Students should play the game for at least 30 minutes, and think about the following questions as they play.

- *In the game, what three substances are made by Biobot Bob?*
- *Who can explain why Biobot Bob needs to make glucose? Methanol? Tear gas?*

On the first day back in class after your students have played the game as homework, begin the class with a Quick Write. Give students 10–15 minutes to answer the questions above. Collect their written responses, and have a brief (5-minute) conversation about their answers.

Classroom Instruction: Photosynthesis

Implement your unit as usual, including the usual hands-on activities, video clips, and reading and writing assignments. Instruction should include the parts of the plant and their roles in the process, the structures where the process occurs, the need for light energy from the sun, the role of water and carbon dioxide, and the photosynthesis equation.

The PowerPoint (PPT) included here will serve as a complement to your photosynthesis instruction. Review the entire PPT beforehand and decide how you want to use it. You may wish to use the entire PPT as an introduction to instruction, or as a review after instruction. You may prefer to pause the PPT after certain slides to ask questions, or you may wish to use just some of the slides to cover a particular concept.

For example, you may want to use the slides about photosynthesis when you teach that topic and then continue with the respiration slides as you cover that concept.

Or, you may choose to use the PPT presentation in its entirety after you complete lessons about photosynthesis and respiration.

Students will likely recognize the images from the game in the glucose production animation. Point out the connection and review what the different atoms are.

Link concepts from your photosynthesis instruction to the appropriate parts of the game. For example, after learning about the need for light energy from the sun and the role of water and carbon dioxide, ask students the following questions:

- *Why can't Biobot Bob make glucose in all parts of the cave? What environmental conditions are required for photosynthesis?*
- *How does Biobot Bob manage to make glucose? How is this the same or different from how a green plant makes glucose?*

Once students are familiar with photosynthesis, the following linking activity can help them make connections between your instruction and the game.

Linking Activity 1
Molecules in Motion 1: Photosynthesis
Once students are familiar with the photosynthesis equation, you should carry out the *Molecules in Motion 1* curriculum linking activity. During this class period, students engage in a kinesthetic activity where they play the role of atoms to form molecules. It is valuable for reinforcing the arrangement of atoms and molecules in the process of photosynthesis.

In this activity, each student is given the role of an atom and is given a card that designates what atom they are. The photosynthesis equation requires 36 atoms. If you do not have that many students, some students may need to assume the role of a molecule (oxygen, hydrogen) and hold two oxygen or two hydrogen cards.

You will need
- 6 carbon atoms (represented by six students)
- 12 hydrogen atoms (12 individual students, or six students each holding two hydrogen atoms, depending on size of class)
- 18 oxygen atoms (18 individual students, or nine students each holding two oxygen atoms, depending on size of class)

As many as 36 students can do the activity if they all have one atom.
As few as 21 students can do this activity, if six students each hold two hydrogen atoms and nine students each hold two oxygen atoms.

Procedure
1. Put the photosynthesis equation up on a poster, white board, or smartboard facing the students, and tell them that they will create the photosynthesis reactants.

2. Give each student a card or cards with the designated atom symbol.

Carbon Dioxide

3. Begin by asking students to come to the front of the class and create one carbon dioxide molecule. Each student should hold his atom card(s) in front of himself.
4. Then ask any remaining carbon and oxygen students to create five more carbon dioxide molecules, so that there is a total of six carbon dioxide molecules in the front of the class.
5. Have students return to their seats.

Water

6. Ask student volunteers to come to the front of the class and create one water molecule. Each student should hold his atom card(s) in front of himself.
7. Once again, ask any remaining hydrogen and oxygen students to create five more water molecules, so that there is a total of six water molecules in the front of the class.
8. Then have these students return to their seats.

Reactants

9. Ask one group of carbon dioxide and one group of water molecule students to position themselves as the reactants of the photosynthesis equation. Remind them that there should be six molecules of each, but that there are not enough students to have this happen.
10. Assign yourself to the role of the Sun.
11. Tell the remaining students that they will position themselves so that they represent the products of the photosynthesis equation. Ask student volunteers to come to the front of the class and create one glucose molecule. Students from the reactant molecules will have to join these students in order to create the glucose molecule.
12. The idea is that the same carbon atoms that make up the carbon dioxide molecule make up the backbone for the glucose molecule. Once students are in the correct positions, ask them what other product they must create, and have volunteers create the final six oxygen molecules.

Sense-Making Discussion: Photosynthesis

Conduct a discussion about the similarities and differences between what students did in this activity and their experience with the *Ruby Realm* game.

Set up chart paper or write on a white board or smartboard that will remain posted throughout the unit. Ask students about the connections between what they did in this linking activity and what they experienced in the game. Be sure to get several student responses and post them on the chart paper/white board or smartboard. Use the following questions to guide the conversation.

- *Does the activity we just did remind you of the game? If so, how?*

- *What kind of, and how many, molecules were represented in the activity? Is that the same or different from the kind and number of molecules in the game?*
- *Explain how you arranged the molecules in the game.*
- *What were the reactants (inputs)?*
- *What were the products (outputs)?*
- *Was there anything that was in the activity that was not represented in the game?*

At this point, have the students play *The Ruby Realm* game again. After students play the game, ask them if they have something new to add to their ideas about the similarities and differences between the activity and the game experience. Use the following questions to guide the conversation.

- *Did you notice anything new from the game?*
- *Is there anything you'd like to change or remove from your previous ideas?*

Classroom Instruction: Respiration

Implement the Respiration part of your unit as usual, including the usual hands-on activities, video clips, and reading and writing assignments. Instruction should include the parts of the cell where respiration occurs; the role of oxygen in the process; the release of energy, carbon dioxide, and water; and the similarities and differences between photosynthesis and respiration..

You can integrate the PowerPoint at a point that makes sense for your unit to review respiration and the connection between the game and your instruction. Students will likely recognize the images from the game in the PowerPoint. You can point out the connection and go over what the various atoms are.

Here too, it is possible to link several concepts from your classroom instruction about respiration to parts of the game. For example, after learning about the process of respiration and the role of respiration in plants, students could be asked the following questions.

- *What does Biobot Bob do with the glucose it produces? How is this like or different from the reason plants produce glucose?*
- *What happens if Biobot Bob runs out of energy? What must Biobot Bob do to restore its energy?*
- *How does Biobot Bob undergo respiration? How is this like or different from respiration in plants?*
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Make sure to take this opportunity to distinguish between the parts of the game that illustrate photosynthesis and those that illustrate respiration.

Once students are familiar with the process of respiration and the products and reactants, use the following linking activity. Students will engage in a kinesthetic

activity in which they play the role of atoms to form glucose and oxygen molecules that then break apart. The activity is valuable for reinforcing the arrangement of atoms and molecules in the process of respiration.

Linking Activity 2
Molecules in Motion 2: Respiration
Just as in Linking Activity 1, each student is given the role of an atom (or molecule) of carbon, hydrogen, or oxygen, and is given a card (or cards) to designate the atom(s) s/he represents. This time, ask students to decide how to act out the process of respiration by positioning themselves to represent the reactants and then the products of respiration. Have groups of students portraying molecules name the substances they represent—carbon dioxide, water, glucose, or oxygen.

You will need

- 6 carbon atoms (represented by six students)
- 12 hydrogen atoms (12 individual students, or six students each holding two hydrogen atoms, depending on size of class)
- 18 oxygen atoms (18 individual students, or nine students each holding two oxygen atoms, depending on size of class)

As many as 36 students can do the activity if they all have one atom.
As few as 21 students can do this activity, if six students each hold two hydrogen atoms and nine students each hold two oxygen atoms.

Procedure

1. Put the respiration equation up on a poster, white board, or smartboard facing the students and tell students that they will create the respiration reactants.
2. Give each student a card or cards with the designated atom symbol.
3. Begin by asking for student volunteers to come to the front of the class and create one molecule of glucose.
4. Ask for student volunteers to create one oxygen molecule, since there will not be enough students to create six oxygen molecules. Make sure to check that students understand that there should be six oxygen molecules at this point.
5. Have students representing the one oxygen gently break apart the glucose molecule.
6. Next, ask student volunteers to create one molecule of each of the products of respiration—carbon dioxide and water.

Sense-Making Discussion: Respiration
Lead a discussion about the similarities and differences between what students did in the activity, what they did in the game, and what they learned during your instruction. Ask the following questions.

- *Does the activity we just did remind you of the game? If so, how?*
- *What chemical reactions do you see represented in the game?*
- *What kind of, and how many, molecules were represented in the activity? Is that the same as, or different from, the kind and number of molecules in the game?*
- *For each chemical reaction, what are the reactants and the products? In what ways do the products differ from the reactants?*
- *Is the product a new substance? Why or why not?*
- *In the natural world, do you think the three products that Biobot Bob produces can all be made from the same raw materials? Explain your thinking.*

Once again, have students play the *Ruby Realm* game for respiration. After students play the game, ask them if they have anything new to add to their ideas about the similarities and differences between the activity and the game experience. Use the following questions to guide the conversation.

- *Did you notice anything new from the game?*
- *Is there anything you'd like to change or remove from your previous ideas?*