EXPLORING PHOTOSYNTHESIS WITH RUBY REALM

Ruby Realm

This game targets the difficulty students have in understanding how the energy from sunlight breaks apart water and carbon dioxide molecules to produce stored energy (glucose) in plants. Photosynthesis is commonly covered in middle-grade science as part of a larger unit of study about cells, plant growth, or ecology. Students typically learn the formula for photosynthesis, and conduct experiments that demonstrate the influence of sunlight on plant health and growth. However, the role photosynthesis plays in plant growth is the subject of one of the most widely recognized scientific misconceptions—that plants grow by converting soil into plant matter. Students often understand that plants capture energy from sunlight in some way, but typically they do not connect the use of that energy with the conversion of water and carbon dioxide into glucose.

Using Analogies

One strategy for engaging students in high-level reasoning is the use of analogy. Analogy helps students to connect familiar concepts and ideas to new learning. In the *Ruby Realm* game, the "source" analog is the need to make sure the robot has sufficient fuel to make his way through the maze by moving him to a sunny spot to make glucose for fuel and completing the glucose-making puzzle where the sun blasts molecules of carbon dioxide and water, separating them into their component atoms of carbon, oxygen, and hydrogen. These atoms are rearranged into two new molecules, glucose and oxygen. The "target" is the concept that plants, with the help of sunlight, convert water and carbon dioxide into starch or glucose, which they use for energy and with which they can grow and build new plant matter.

The following instructional techniques **(A–F) are ones that researchers[1] have found are effective for mapping analogies during instruction.**

A: Use a familiar "source" analog (structures or processes students already understand) to connect students to the "target" being taught.

[1] Richland, L. E., Zur, O., & Holyoak, K. J. (2007). Cognitive supports for analogy in the mathematics classroom. *Science, 316*(5828), 1128–1129.

B: Present the "source" analog visually.

C: Keep the "source" analog visible to learners during the comparison to the target.

D: Use spatial cues to highlight the alignment between the corresponding elements (i.e., draw parallel diagrams, use a table that aligns the elements of the source and target concept).

E: Use hand or arm gestures to point to the source and then the target.

F: Use mental imagery or visualization by referring to a familiar mental image from the game or from real life.

In addition to discussing the similarities between the game and the concept, it is important also to pay attention to the differences between the game and the concept, and where the analogy breaks down. For example, plants do not create tear gas like the robot does in the game.

Below is an instructional sequence showing how to apply analogy mapping techniques to *Ruby Realm*. It includes analogical strategies to help students understand how the game they played is like, or different from, science concepts they are learning.

Because class times vary across schools, we have organized the sequence into a series of "steps," rather than lessons. This allows teachers to adapt the sequence to fit their particular schedule. For example, teachers with 45-minute class periods might do Step 1 and Step 2 on the first day, while a teacher with 70-minute class periods might do Steps 1-3.

Step 1 (*35–40 minutes*): Gameplay

Play the game for 35–40 minutes before you begin your unit on photosynthesis.

Step 2 (*5 minutes*): Exit Ticket

At the end of the class, pass out the **Exit Ticket,** which asks students what they think was the goal of the game. Review the Exit Tickets to help you with the discussion for the next session.

Step 3 (*30 minutes*): Game Debrief Presentation

The Purpose

The purpose of the debrief is to ensure that students have a shared understanding of the basic mechanics and goals of the game. Our focus is on energy transfer in the context of photosynthesis.

Throughout the Game Debrief Presentation:

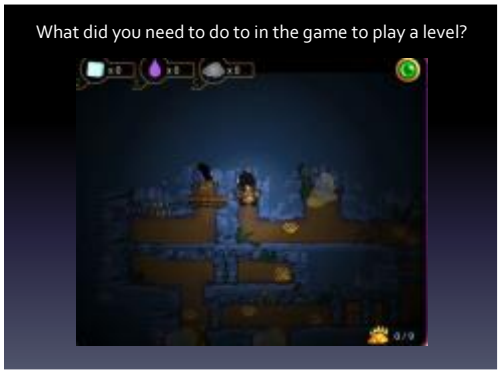
- Make sure the animation is playing on each slide, not just a static image;
- Ask more than one student to respond to the questions;
- Have students come up to the whiteboard, point to the presentation animations, and describe what they did as they played the game;
- Encourage students to build on others' responses in the discussion;
- Keep the PPT animations displayed throughout the entire lesson.

The Process

Start the Game Debrief Presentation**.**

Slide 1: What did you have to do in the game to play a level?

- Important points to listen for:
  - Bob needs energy to move through the cave and blast through walls.
  - Students also will likely mention navigating through the maze, getting gold, avoiding vampires, deflecting bats, and how the Robot uses tear gas and methanol, making the words to open the vault.



Slide 1 of the Game Debrief Presentation

Slide 2: What are some of things that you had to do when Bob ran low on energy?

- Important points to listen for:
  - The game required them to:
    - Help Biobot Bob capture light energy by standing in the light;
    - Use sunlight to break apart carbon dioxide and water molecules.

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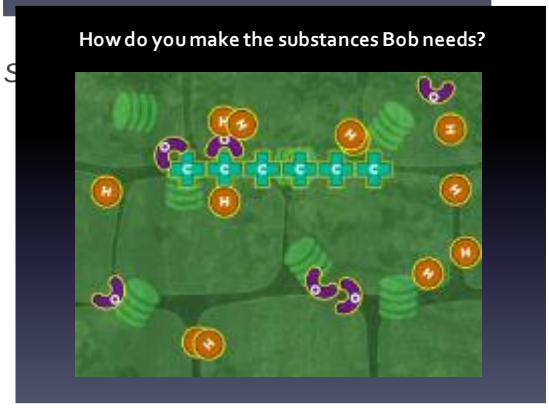
Slide 3: How do you make the substances Bob needs?



Slide 3 of the Game Debrief Presentation

EDC Learning transforms lives.

- Important points to cover:
  - That students made a glucose molecule by rearranging the carbon, hydrogen, and oxygen atoms from the water and carbon dioxide molecules;
  - Glucose provides Biobot Bob with energy;
  - Students might also mention making methanol and tear gas molecules as well, from the same molecules.
- When students mention the glucose or the hydrogen, oxygen, and water, point to them or have the students come up and point to what they are describing.

Slide 4: How do you win the different levels of the game?

Important points to listen for:

- In the game, you have to figure out how to get Biobot Bob through the cave in order to find the lost friends. Bob needs energy in the form of glucose to move through the cave. Sometimes he runs low or out of energy, and you have to help him. He needs light so he can split molecules of carbon dioxide and water into carbon, oxygen, and hydrogen atoms.

Slide 5: What are some strategies you figured out to win the game?

Have students describe the strategies they used to play the game.

Step 4 (*10-15 minutes*): Photosynthesis Instruction— Introduction

Present the first 12 slides in the Photosynthesis Instruction Presentation that we provide, which focus on the process of photosynthesis, including 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, and the role of water and carbon dioxide.

Step 5 (*30 minutes*): Photosynthesis Instruction—Molecules in Motion Activity

Leave slide 12 up as you have students do the Molecules in Motion activity. In this activity, groups of three or four students are provided with a set of 36 index cards. Six of the cards have a *C* on them, representing carbon, 12 of the cards have an *H*, representing hydrogen, and 18 of the cards have an *O*, representing oxygen. Ask the students to create the molecules on the left side of the slide with their atom cards. These are the *reactants* of photosynthesis. If you run the animation, it will show the atoms moving to the right side of the slide, making glucose and oxygen. You can shine a light on the reactants to represent sunlight. Ask students to make the *products* of photosynthesis with their cards. If students need extra support, you can provide handouts of the slide to place on the table or desk, which may make it easier for the students to see how to position the cards.

Step 6 (*10-15 minutes*): Photosynthesis Instruction—Summary

Present slides 13-15 in the Photosynthesis Instruction Presentation that we provide, which focus on clarifying the process of photosynthesis, including the products of photosynthesis, the photosynthesis equation, and the kind of energy transfer (light to chemical) that occurs.

Step 7 (*15 minutes*): Revisit Game

Have students play the game again.

Step 8 (*30–40 minutes*): Analogy Mapping Presentation

Map the elements of the game that align to the content to build from students' knowledge of the game and help solidify their new knowledge.

Project the Ruby Realm Analogy Mapping Presentation. Each slide will have an animation from the game (the source), and an image that shows a flower in the sunlight and the reactants and products of photosynthesis (the target). For each discussion question, there are two slides. One is a slide with a question to ask students, and the other slide provides the answer to the question. During the presentation

- **Make sure the animation is playing on each slide, not just a static image;**
- **When presenting both the question and answer slides, point between the game animation and the flower image.**
- **Ask more than one student to respond to the questions;**
- **Have students come up and point to the presentation animations and describe what they did as they played the game;**
- **Encourage students to build on others' responses in the discussion;**
- **Keep the PPT animations displayed throughout the entire lesson.**

POST ASSESSMENT

If you would like to have students complete a photosynthesis assessment after the unit, we recommend three resources. The American Association for the Advancement of Science Assessment website [link to http://assessment.aaas.org] and the Misconceptions-Oriented Standards-Based Assessment Resources for Teachers website [link to https://www.cfa.harvard.edu/smgphp/mosart/] provide high-quality multiple-choice assessment items that have been rigorously tested with students. You can find open-ended assessments in the Uncovering Student Ideas in Science series of formative assessment probes

[link to http://www.nsta.org/publications/press/uncovering.aspx], written by Page Keeley and published by NSTA Press.