EXPLORING HEAT TRANSFER WITH GALACTIC GLOOP ZOO

Galactic Gloop Zoo

This game, *Galactic Gloop Zoo*, is designed to address a common misconception among students—that cold moves through space along with heat. Ordinary language supports this idea through such expressions as "Don't let the cold in." The game also addresses the difference between heat and temperature. The mechanics of the *Galactic Gloop Zoo* game provide a model for the transfer of heat via radiation, convection, and conduction. The player has to bring enough heat to a set of fertilized eggs in a variety of different environments to cause them to hatch various types of creatures and populate a zoo in outer space. The game also addresses the concept of how thermal energy moves from hot to cold until a state of thermal equilibrium is reached.

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 *Galactic Gloop Zoo* game, the "source" analog is the animation of the zookeeper, the gloops, and the eggs turning shades of red and white as they touch or come near each other in water-filled rooms or in rooms with no air, along with the numbers indicating their changing temperatures. The "target" is the transfer of heat by conduction, convection, or radiation as a mechanism for warming or cooling objects.

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.

B: Present the "source" analog visually.

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

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, not all objects turn red as they heat up and white as they cool down.

Below is an instructional sequence for a series of lessons on heat transfer that include the use of *Galactic Gloop Zoo*. It includes all of the 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 (gameplay) and Step 2 (exit ticket) on the first day, Steps 3 and 4 on the second day, and so on.

Step 1 (*35–40 minutes*): Gameplay

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

Detail of Level 8 of Galactic Gloop Zoo

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 (*20–30 minutes*): Game Debrief

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 heat transfer.

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 PPT**.**

Slide 1: How do you win the different levels of the game?

- Important points to listen for:
  1. Eggs need to be hatched. They have to be the right temperature to hatch.
  2. Stan uses his own touch or sends gloops to transfer heat energy. The energy is transferred to heat the eggs or to cool the eggs, to get them to the right temperature.
  3. Players have to use gloops when there are obstacles that prevent Stan from reaching the egg.

Slide 1 of the Debrief PPT

Slide 2: What did you have to do to in the game to play a level?

Important points to listen for:

- The gloops need to be a certain temperature to get past the various obstacles, and Stan helps them get to the correct temperature.
- Stan sometimes touches eggs or gloops. If he is hotter than they are, his heat energy is transferred to the egg or gloop. If he is cooler, the heat energy is transferred from the egg or gloop to him.

  - Sometimes the heat energy is transferred through contact, and sometimes it is transferred through the water or air.

Slide 3: What happens when the colors in the game change from red to pink to white? (Animation of red Stan touching a gloop and turning it from white to pink.) [B]

- **Important points to listen for:**
  - When a red (hot) object and a white (cold) object touch, whatever is red becomes pink and whatever is white becomes pink.
  - The red object doesn't stay red. It is losing or transferring heat as the other object is gaining heat energy.
  - In some rooms, objects must touch to change color. In some rooms, they do not.

Slide 4: What do the arrows mean?

- **Important points to listen for:**
  - Heat is transferring to the cold object.
  - The arrows show the direction of the heat.

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 (*30-40 minutes*): Heat Transfer Instruction: Conduction Activity

Have students do the "Feel the Heat" that we provide.

Step 5 (*10-15 minutes*): Heat Transfer Introduction Intro and Conduction

Present the four introductory slides at the beginning of the conduction/convection/radiation Heat Transfer PPT that we provide.

Step 6 (*40 minutes*): Heat Transfer Instruction: Convection

Have students do the "Mix the Heat" that we provide. Show the Convection section of the Heat Transfer PPT that we provide.

Step 7 (*40 minutes*): Heat Transfer Instruction: Radiation

Have students do the Infrared Meter activity Show the Radiation section of the Heat Transfer PPT that we provide.

Step 8 (*15 minutes*): Revisit Game

Have students play the game again.

Step 9 (*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 *Galactic Gloop Zoo* mapping PPT Each slide will have an animation from the game (the source) and images related to conduction, convection, and radiation (the targets). 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 images of heat transfer;**
- **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 ASSESSMENTS

If you would like to have students complete a heat transfer 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 [link to http://www.nsta.org/publications/press/uncovering.aspx] series of formative assessment probes, written by Page Keeley and published by NSTA Press.