Modeling GEYSER Eruptions in the Classroom

by Stephen Mattox and Christine Webster

Watching Old Faithful transform from a smoldering mound to an explosive 50-meter high geyser is enough to generate awe in any observer. Behind this stunning, visual geologic display is a triad of heat, water, and plumbing that rarely unify on our planet. But geologists aren't the only scientists drawn to geysers. Biologists have recently recognized thermal features as a habitat of interesting bacteria that thrive in extreme conditions and may provide clues to the origin of life. Engineers tap into the steam and hot water found in thermal areas around the Pacific Rim to generate electricity without releasing the carbon dioxide associated with fossil fuels.

Geysers provide an excellent opportunity to explore the Earth system as described by the National Science Education Standards (content standard D for grades 5–8). By using the geyser model activity described in this article, students can investigate the relationship between the hydrosphere, geosphere, and biosphere. In addition, students will be able to develop descriptions, explanations, and predictions using the model as a guide for their exploration and apply their thinking to their local setting.

How geysers work

During an eruption cycle, groundwater flows laterally to recharge a shallow plumbing system (Figure 1). The water is heated by the surrounding hot rock. Pressure (and boiling temperature) varies in the system depending on the depth of water. As hot water turns to steam, bubbles form and grow on the walls of the chamber. Large bubbles collect in narrow passages and generate higher pressure. Eventually gas pressure drives water out at the surface. Once water belches onto the surface, pressure in the entire system is released. Superheated water expands into the areas formerly occupied by the water and converts to steam as pressure drops in the system, ejecting a fountain of water and steam. When the gas pressure below is relieved, the eruption ends. The eruption cycle continues as groundwater flows laterally to recharge the system, heat is added, and pressure builds.

Safety first

Safety is paramount because the model involves boiling water. Wraparound safety glasses are required for all students. The model should be assembled on a lab table that students can gather around, but they should be kept at least three meters from

CAUTION

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the model during the eruption cycle. Boiling water commonly erupts about 1 to 2 meters above the titration tube. In addition to safety glasses, the demonstrator should wear insulated gloves and a lab apron. Start the eruption by simply turning the hot plate on. If needed, the hot plate can be turned off by unplugging it at the wall.

The discussion before the eruption

To engage students, ask those who have seen a geyser in person to describe its behavior, appearance, surrounding geology, and location. Next, distribute the student activity sheet with questions (page 45), which will lead students through the activity. The first step of the activity is for students to sketch the model setup. They then make observations, which will center around the formation of bubbles within the system. Bubbles begin to form in only a few minutes. Students will need to be about one meter from the flask to see the bubbles. If the bubbles are difficult to see, add a backdrop of colored paper or a few drops of dye to the water. Students should also explain how the model compares to real geysers. Specifically, they need to explain that a source of energy is needed to convert the liquid to a gas in both systems. The energy is provided by hot rock and magma in a geyser and by the hot plate in the model.

Students continue to make observations through several eruption cycles. During a typical run, the model can erupt 20 to 25 times in a five-minute period. Stopwatches can be used to time the length of each cycle. An eruption cycle is defined as the time from one eruption to the next. An eruption occurs when water is forced out of the tube. Eruptions will continue as long as water is available, heat is supplied, and the "plumbing" remains intact (no leaks or breaks). When the volume of water is low, the eruptions tend to be larger because the ratio of gas to water has increased. Guide the students toward this observation with questions such as, What is changing in the system?, Why is it changing?, and Does this happen in real geysers? After observing a few cycles, students return to their desks to complete their activity sheets.

Classroom discussion

The following is a summary of what to look for when assessing students' responses on the activity sheet. If time permits, the responses can be shared and discussed with the class as a whole. Responses to questions 6 through 13 provide an assessment of student understanding. See answers below (in italic).

1. Make a drawing of the setup in front of you. Label as much as you can.
   Compare to Figure 2. The drawing should include the heat source, plumbing, and water.
2. As the water begins to boil, record in detail what is happening. (Hint: Look for bubbles.)
   As evaporation occurs, small bubbles form on the bottom of the flask. The bubbles rise up towards the top of the flask. This is the onset of the process. The bubbles are not yet leaving. They are in the flask. The bubbles are accumulating, growing, coalescing, but the system is open at the top of the titration tube.

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Building the geyser

Materials

- a 50-mL titration tube
- a 500-mL Erlenmeyer flask
- a solid rubber stopper (#7) that will fit the mouth of the flask
- ring stand
- a hot plate
- three or four stopwatches
- burette clamp (metal)
- water
- safety glasses

Procedure

1. Use a power drill with a steel bit to drill a hole in the rubber stopper just big enough so that the titration tube can be snugly inserted. Alternatively, order a one-hole rubber stopper. The seal between the stopper and tube should be tight.
2. Slide the tubing far enough into the stopper so that, when the stopper is inserted into the flask, the tubing will reach 1–2 cm above the bottom of the flask.
3. Fill the flask with 150–200 mL of water.
4. Place the flask on the hot plate.
5. Insert the stopper-tubing setup into the neck of the flask.
6. Secure the upper end of the tubing to the ring stand with the burette clamp. See Figure 2 for a picture of the completed setup.

Note: Experiment ahead of time with the temperature settings on the hot plate to find a temperature that will bring the water to a boil five to ten minutes after it is turned on. You will use this time for a discussion of the processes involved.

FIGURE 1 **A subsurface model for Old Faithful in eruption**

FIGURE 2 **Geyser activity setup**

3. What are the bubbles doing to the level of the water?
   The expansion of bubbles as they rise up the tube is forcing the water up the titration tube. The steam and the expanding heated air trapped in the system create the pressure.
4. How long does it take for water to rise, erupt, and then lower?
   Times vary from about 10 to 25 seconds.
5. Time three more eruptions and record their durations.
   Times vary from about 10 to 25 seconds.
6. Based upon what you have observed, list three factors that are needed to make an eruption.
   Heat, narrowness of tube, and water.
7. How is water heated close to the Earth's surface?
   By hot rock or magma.
8. What is the supply of water for a geyser?
   Groundwater that is recharged by surface water.
9. Using the list from question 6, what would be the greatest determining factor as to how high the eruption would go into the air? Explain your answer.
   Answers will vary but key aspects are intensity of heat, amount of gas pressure, and diameter of the tube.
10. In the eruption cycle data, were the times similar? Explain why or why not.
    In general, yes. Once the system began to erupt, it quickly ejected most of the water and steam. It took a bit longer to get the last bits of water and steam out.
11. Why did the eruption stop? Give two explanations.
    Most of the water was ejected or there was too little gas to eject what water was left.
12. Compare and contrast Figure 1 with the model drawing you made in question 1. Write your answers in the table below.
    See completed table below.
13. Based on your observations, explain the presence or absence of geysers in
    - Yellowstone *(hot rock, shallow groundwater, good plumbing all present)*
    - Hawaii *(groundwater is too deep)*

- Michigan *(midwestern states, no heat source)*
- Your home state *(varies)*

Answer to question 12: Comparison of the model geyser to real geysers

	Model	Geyser
Heat source	Hot plate	Magma or hot rock
Water	Small volume of water from the tap	Larger volume of water that is replaced by surface runoff and supplied by groundwater
Plumbing	Plumbing is a straight glass tube	Plumbing is complex with narrow curved tunnels
Pressure	Weight of water column	Weight of water column
System	Closed to water recharge but open to atmosphere	Open system
Erupted material	Steam and/or water	Steam and/or water
Eruption cycle	Tens of seconds	Constant to years
Eruption size	Eruption is several centimeters up into the air over an area of about 100 square cm	Eruption can be up to hundreds of meters high over an area of hundreds of square meters
Geographic distribution	Classrooms everywhere!	Ring of Fire, some hot spots
Host for thermo-philes	None	Some

Extension questions

- How could the model be modified to generate electricity? Would this system be energy efficient? Would it be comparable to geothermal power plants?
- Repeat the activity and vary the following: The volume of the flask, the shape of the flask, the height of the water column, and/or the diameter of the glass column.
- Suggest how the model could be modified to erupt every hour, to erupt larger volumes, or to erupt higher into the air.
- Compare the new eruptions to real geysers.

Reference

Keefer, W. R. 1972. The geologic story of Yellowstone National Park. *U.S. Geological Survey Bulletin* 1347: 92.

Student activity sheet

1. Make a drawing of the setup in front of you. Label as much as you can.
2. As the water begins to boil, record in detail what is happening. (Hint: Look for bubbles.)
3. What are the bubbles doing to the level of the water?
4. How long does it take for the water to rise up the tube, erupt, and then drop back down? This is an eruption cycle. Begin timing the cycles after the first eruption.
5. Time three more eruptions and record their durations.
6. Based upon what you have observed, list three factors that are needed to make an eruption occur.
7. How is water heated close to the Earth's surface?
8. What is the supply of water for a geyser?
9. Using the list from question 6, what would be the greatest determining factor as to how high the eruption would go into the air? What would you modify to make a shorter/higher/longer eruption? Explain your answer.
10. In the eruption cycle data, were the times similar? Explain why or why not.
11. Why did the eruption stop? Give two explanations.
12. Compare and contrast Figure 1 with the model drawing you made in question 1. Write your answers in the data table below.
13. Based on your observations, explain the presence or absence of geysers in
    - Yellowstone,
    - Hawaii,
    - Michigan (midwestern states), and
    - Your home state.

Comparison of the model geyser to real geysers

	Model	Geyser
Heat source		
Water		
Plumbing		
Pressure		
System		
Erupted material		
Eruption cycle		
Eruption size		
Geographic distribution		
Host for thermophiles		