



Earth System in a Bottle

Purpose

- To acquaint students with the hydrosphere, geosphere, atmosphere, and biosphere more closely.
- To have students use microcosms to study natural phenomena.
- To introduce students to the concept of a “fair test” in a scientific investigation.

Overview

In pairs, students will create experimental conditions in terrariums in order to study what plants need to live. Variables to study include the presence or absence of soil, water, and sunlight. Students will record the growth of radish plants as well as observations of “the water cycle” in their terrariums. At the conclusion of their experiments, students will share their results with the class and discuss how water, Earth materials, and air are all necessary to support living things.

Student Outcomes

After completing this activity, students will know about the importance of the hydrosphere, geosphere, and atmosphere in supporting the biosphere. They will learn how to set up “fair tests,” record detailed observations, use drawings as scientific records, make sense of experimental results, and share them publicly.

Science Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry

Science Content Standard C: Life Science

- The characteristics of organisms
- Organisms and environments

Science Content Standard D: Earth and Space Science

- Properties of earth materials

Time

- Part 1: One 30-45 minute class period
- Part 2: One 30 minute class period
- Part 3: 15-20 minutes three times a week
- Part 4: One 45 minute class period

Level

Primary (most appropriate for grades K-4)

Materials

Part 1:

- Elementary GLOBE book: *All About Earth: Our World on Stage*
- Two blank wall charts

Part 2:

- One of each of the following per group of students (2 – 4 students): 2 1-liter clear plastic soda bottles, 3 cups potting soil, 10 radish seeds, measuring cup, water, tape, permanent marker, index card, foil, paper towels
- *Earth System in a Bottle Recipe Card* – one copy for each student or group of students

Part 3:

- Multiple copies for each student of the *Earth System in a Bottle Student Activity Sheet* (and a folder to hold these papers)
- Overhead transparency of the *Earth System in a Bottle Student Activity Sheet*

Part 4:

- Wall charts from Part 1



Preparation

Part 1:

- Read the Elementary GLOBE book *All About Earth: Our World on Stage* – either read it to the class or have students read it to themselves. The book can be downloaded from www.globe.gov/elementaryglobe.
- Make two wall charts titled: “What do plants need to live?” and “What do we want to learn?”

Part 2:

- Make a copy of the *Earth System in a Bottle Recipe Card* for each student or group of students. Optional: laminate the recipe cards so they won't get wet during this activity.

Part 3:

- Make copies of *Earth System in a Bottle Student Activity Sheet* so that each group has a blank sheet for each observation they make. Make a folder for each group. Another option is to make smaller photocopies of the activity sheet so you can fit two sets of the sheet on each piece of paper (using landscape formatting).
- Prepare the soda bottles by cutting them as shown in Figure 1.

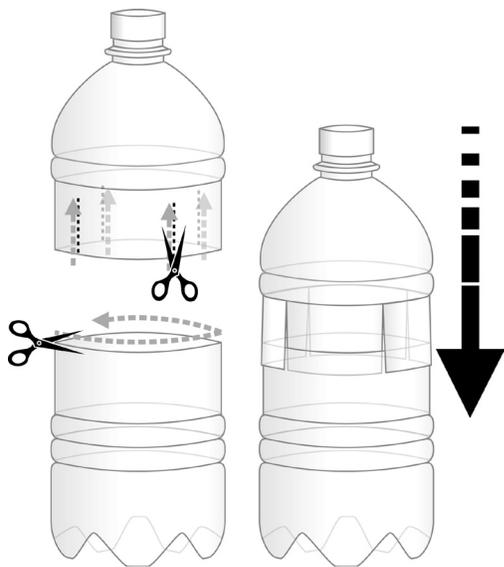


Figure 1: Cut bottle in half and cut vertical slits as shown. Slide top over bottom of bottle, pushing alternate flaps to the inside.

- Prepare stations at which student groups can plant their terrariums.
- Plant one terrarium ahead of time to determine the correct ratio of soil to water. The amount of water needed to thoroughly moisten about 3 cups of soil will vary depending on the type of soil available locally and on the initial moisture content of the soil.
- Spread some of the soil in a large tray, baking sheet or on newspaper and set it to dry out (preferably in a sunny window) for two days. This soil will be used in the “No water” treatment.

Part 4:

- No preparation necessary.

Teacher's Notes

In this activity students will plant some control terrariums that have all the elements a plant needs to grow (soil, water, light) and other experimental terrariums that lack one of these elements. They will monitor their terrariums closely to gather data on what plants need to grow.

Science background:

Plants need the following things in order to grow: Soil, Water, Light and Air (oxygen and carbon dioxide).

Soil:

Plants need soil to anchor their roots. They also absorb through their roots necessary minerals dissolved in the water contained in soil.

Water:

Like all living things, plants need water to survive. Plants need water to soften the seed coat - a process that begins germination - and to maintain all their life functions. Water evaporates from the surface of plant leaves in a process known as “transpiration.” This evaporation provides the force that allows the roots to draw water up from the soil. Transpiration also cools the plant, just as the evaporation of sweat from our skin surface cools us! Transpiration accounts for 10% of all water contributed to the atmosphere in the form of water vapor.



A note about the phases of water: Individual molecules of water are continually leaving the surface of liquid water (evaporating) and entering the air in the gas phase. Water in the gas phase (water vapor) is completely invisible. Steam, fog and clouds (visible water in air) consist of tiny droplets of water that have condensed on particles in the air.

Air (oxygen, carbon dioxide, and nitrogen):

Plants breathe (respire). Like all living things, they respire to support their life functions and give off carbon dioxide as an end product of respiration. During the daylight hours, they take in carbon dioxide which they use in the process of photosynthesis. They capture the sun’s energy and use it to synthesize sugars and other molecules, using carbon dioxide molecules as “building blocks.”

Fair test:

A fair test is an investigation or experiment in which one condition (called the “independent variable”) affects another (“dependent variable”) while all the other conditions in the investigation are not changed. In all the experiments, plant growth is the dependable variable. For example, the bottle wrapped in foil only has light excluded (the independent variable), while it has the same amount of soil and water as the other treatments; the difference in plant growth (the “dependent variable”) compared with the plants that receive soil, sun and water (the “control”) can then be attributed to the absence of light, since the investigation was a fair test. Since nothing else was changed, the outcome is not confused or “confounded.” *For this activity, the terrarium that contains soil, water, and light is the “control” terrarium, and the three terrariums that are missing one element (soil, water, light) are the “experimental” terrariums.*

Student ideas about what plants need:

- Students may mention CO₂ and may even list it as one of the needs of plants. Rather than entering a discussion about it, simply acknowledge that indeed, it’s a gas in air and that if the plants have air in the bottle (which they do) the students can assume that the plants will get CO₂.

- Some children may say plants can live without water, based on prior experience with terrariums, or knowledge of desert plants. Of course, strictly speaking, all plants need water.
- Students may have tried to grow plants in pure sand as a contrast to soil, with varying success.

Logistics for planting with students:

Planting is manageable as a whole class activity if you have one adult per student group. Other options: Have students plant, with your help, one group at a time while the rest of the class is engaged in other activities.

Things to note about the making an Earth System in a Bottle:

- Seed depth: Be sure to tell students to plant the seeds only as deep as the seeds are wide. If seeds are planted too deep, the emerging seedling will take longer to find the surface of the soil.
- The order of planting is important: Add the water to the soil before adding the seeds. Otherwise, the seeds will float to the surface if watered after planting.
- Soil compacting: Students will pack down the soil to different degrees of compactness but this shouldn’t affect plant growth.
- Have young students practice measuring the correct amount of water. Often they put too much water into the bottle.

Results to expect in this activity:

- In the terrarium with no water: The seeds will not germinate.
- In the terrarium with no light: The plants will grow long and spindly but the plant will be “etiolated” (because they contain no chlorophyll, the stems will be white or pale green and extremely floppy).
- In the terrarium with no soil: The plants will germinate and grow by anchoring their roots into the paper. Eventually, they will stop growing because a) the roots need soil in which to anchor the plant and paper towel doesn’t provide enough support, and b) the plant ultimately needs the nutrients it gets from soil. Students may conclude from this that plants don’t need soil. Have them



compare the plants to those growing in soil to help them decide.

- Note: Sometimes the seed coat is not shed by the growing seedling but traps the first set of leaves. If this happens, you can expect it to begin to get moldy within the first week.

For more information on using plastic bottles to create terrariums, see *Bottle Biology* at www.bottlebiology.org or www.fastplants.org.

What To Do and How To Do It

Part 1: Discussion and Brainstorming

1. Having read the Elementary GLOBE book *All About Earth: Our World on Stage*, introduce this investigation to the class. Explain to students that they will be using a “micro system” to investigate some of the same Earth systems that the children did in the book, but that they will be doing this from the biosphere (a plant’s) point of view.
2. Ask the students, “What do you think a plant needs to live?”
3. Record their answers on a chart. They will likely mention water, air, sunlight, soil, and perhaps carbon dioxide and oxygen.
4. Once you have given all students the opportunity to respond, explain to them that they will be investigating plants’ need for water, soil, and light.

Part 2: Planting and Predictions

1. Demonstrate how to plant the seeds in the terrarium. See the *Earth System in a Bottle Recipe Card* at the back of this activity for the instructions/recipe.
2. Have students repeat the steps they observed you make during the demonstration. You can also photocopy the *Earth System in a Bottle Recipe Card* at the back of this activity so students can follow along.
3. Each group will plant one “control” version of the Earth system and one “experimental” version of the Earth System. The experimental Earth system

will not have one of the following parts of the Earth system: light, soil, or water. Make sure your class creates at least one of these experimental systems. See the *Earth System in a Bottle Recipe Card* for the list of experimental systems.

4. Have the students write down their predictions on an index card either individually or in their groups for what they expect to see in the experimental Earth system bottle. Tell them they will look at their predictions again at the end of the experiment.

Part 3: Observational Procedures

1. Explain to the students that they will make observations and record them on the *Earth System in a Bottle Student Activity Sheet*.
2. Explain the *Earth System in a Bottle Student Activity Sheet* to the students (using an overhead transparency of the sheet if you wish). Every other day, students will record their names, the date, and the system they are observing. Remind them that each terrarium has air in it, so they will always check that box on the student activity sheet. Then they will observe the plants closely. Give the students cues about what to write about - some ideas are: the number of sprouts or leaves, condensation, plant size, color, mold, roots. They will draw the plants in the bottle and may also write notes alongside. Younger students may need assistance with this.
3. Option: You or your students may want to take digital photos as a record as well.
4. Explain to students that they will make observations for 10-15 minutes at specified times on certain days.
5. You may want to monitor students during the first two observation sessions to make sure they are observing and recording in the manner specified (though any additional information students may want to record is also welcome). Note: At first, teachers might want to model a complete observation session for the class.

Part 4: Sharing Results

1. Once the plants have grown sufficiently to show clear results (this will take 2 to 4 weeks), have the students take some time to study all of the



observations they have made.

2. Next, have them decide in their groups what their data show.
3. Have the students share their findings in a whole class discussion and summarize their findings on a chart.
4. Finally, have the students revisit the predictions they wrote on their note cards and discuss as a class whether or not their conclusions are different.

Adaptations for Younger and Older Students

Younger students may need help taping their bottles shut. You might also want to help them label their bottles. In addition, wrapping bottles in foil securely enough to keep all light out can be a challenge for younger students.

Younger students may only make drawings on the *Earth System in a Bottle Student Activity Sheet* and require adult help to write down what they observed. To help young students write about their observations, put a “word bank” up on the wall of your classroom; this chart can contain words the students might commonly use to describe their observations: plant, grow, tall, green, brown, wet, dry, etc.

You might consider engaging the older students in a discussion of what constitutes a “fair test” for whether plants need water, soil or sunlight. Older students can discuss what they will accept as a “healthy” plant and what their criteria will be for determining what a plant that is getting all it needs might look like.

Further Investigations

- **Scientists’ Journals:** Show your students examples of published journals some well-known scientists kept in the past. Some good examples to use are the journals of Charles Darwin, Henry David Thoreau and Merriweather Lewis & William Clark. Have the students look for examples of interactions

between Earth’s components in these journals.

- **Completing the plant life cycle:** Here are two options for continuing terrarium investigations.
 1. Keep the terrariums undisturbed on the windowsill and have the students discover that the system in the terrarium supports the plants without any further care from them.
 2. Remove the tops from the terrariums and allow plants to continue growing. Depending what time of year you choose for this activity, students might even be able to harvest radishes! Note: once you remove the top of the terrarium you will need to start watering it so the soil doesn’t dry out.
- **Observe other members of the radish family:** Radishes belong to the family Cruciferae, the cabbage family, which contains about 3,000 species. The family was named Cruciferae because the flowers of plants in this family characteristically have four petals spreading in the form of a cross. Farmers and scientists have bred many of the common food plants we eat today from this family (e.g. radishes, turnips, cabbage, cauliflower, and broccoli). Bring examples in and discuss the diversity of this plant family with the students.
- **Literacy Connections:** Read a science trade book about plant life cycles to your students. Some examples are *The Carrot Seed* by Ruth Krauss and *This Is the Sunflower* by Lola M. Schaefer. After reading the story, have the children write/draw on a paper that is divided into four parts with the following headings: 1) Title; 2) “The plant in this story grew because it had ___ (for example, soil and rain); 3) The plant would have grown even better if it had ___ (e.g., more sun or more rain); and 4) My favorite part of the story was when ___.

The “Earth System in a Bottle Learning Activity” was developed in collaboration with Harold McWilliams and Gillian Puttick from TERC, Cambridge, MA.

Earth System in a Bottle Recipe Card

Earth System in a Bottle Recipe

Each group will make two terrariums. All groups will make a terrarium that has all of the parts of the Earth's systems. Then each group will make a second terrarium that is missing one part of the Earth's systems.



Earth System in a Bottle



1. Put about **three cups of soil** in the bottom section of the terrarium and pat the soil gently until it is fairly firm.



2. Add about a **quarter cup of water** and look at the soil from the side to make sure that all of the soil gets wet. If there's still dry soil, add more water.



3. Drop **4-5 radish seeds** onto the surface of the soil. Use your fingertip to push the seeds just below the soil surface. Sprinkle a little more soil on top of the seeds just to cover them.



4. Place the top section of the terrarium on top, pushing alternate flaps to the inside and outside so that it fits securely. Make sure the lip/top is still on the bottle.

5. Tape the top and bottom sections together to create an airtight seal.

6. Label the terrarium with your groups' names and place it on a sunny windowsill (or under a grow light if you have one).

Experiments

Student groups: check with your teacher to decide which of the three experiments below you are doing.



No light

To darken the terrarium, wrap it with a **sheet of foil** large enough to go around the bottle twice. Crimp the foil securely shut over the top and bottom of the bottle.



No soil

Instead of soil, place a thoroughly **moistened paper towel** in the bottle, folded to fit into the bottom section.



No water

Follow the planting directions above except **omit the water**. Be sure to use previously dried soil.

Earth System in a Bottle Student Activity Sheet

Date: _____

This terrarium included:

Light

Soil

Water

Seeds/plants

Air

Draw what you see in this terrarium.



Write about what you see in this terrarium.
