Earth System Science Project

An inexpensive model of a pond ecosystem demonstrates the interaction between the geosphere, hydrosphere, atmosphere, and biosphere

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For several decades, science teachers have used bottles for classroom projects designed to teach students about biology. A model terrarium enclosed in a glass bottle was described in the 1975 edition of *Science and Children* (Ochs and Brock 1975). Since then, numerous adaptations of the "bottle biology" idea have been developed.

Teachers can use inexpensive and easily accessible materials to explore decomposition, fermentation, food chains, and ecosystems in the classroom (Wisconsin Fast Plants 1991; Ingram 1993; Jager 1993; Taylor et al. 1995). Bottle projects do not have to just focus on biology, however. These projects can also be used to engage students in Earth science topics.

The Earth System Science Project described in this article was adapted and developed from the EcoColumn project (Wisconsin Fast Plants 1991) and is geared toward middle and high school Earth science students. Although this activity is reminiscent of other bottle biology projects, the Earth System Science Project was designed to fit specifically into an Earth science curriculum.

Gathering materials

To begin, the teacher introduces the project to students and hands out an information packet that contains the following:

- A list of materials (Figure 1);
- Earth System Science Column assembly and observation instructions (Figure 2, p. 32);
- Guidelines for the first written part of the project (Figure 3, p. 33);
- A data collection chart;
- Guidelines for the second written part of the project; and
- A student checklist.

While most of the materials listed in Figure 1 can be found in the science classroom, some have to be purchased. Guppies, for example, can be purchased at most pet stores for about 10 cents a fish. Fish stores often give away snails and duckweed. Fruit flies can be purchased from biological supply companies, in some cases for less than $5 a vial. One vial can supply enough flies for up to seven columns.

Before the project begins, students should already be familiar with ecosystems, the geosphere, and the water cycle, and should have participated in laboratories exploring the properties of water, acids, and bases. Students should also know how to use water quality test strips.

Assembling the project

Teachers should allot only two classroom days to assemble the Earth System Science Column in order to avoid wasting instructional time.

Both Jager (1993) and Ingram (1993) discuss how the bottles should be prepared and cut. The goal is to cut and assemble the bottles so that the ecocolumn is divided into three chambers—terrestrial, decomposition, and aquatic. On the first day, students cut and assemble their bottles (as shown in Figure 4) by first drawing lines around the bottles and then using scissors to cut along the marked lines (the instructions can be placed on an overhead projector for students to follow).

After students cut the bottles, holes are drilled into three bottle tops (which cap off sections C, D, and F of Figure 4). Holes are drilled into the bottle tops to allow interaction between the different chambers of the column, modeling an ecosystem. For example, flies from the decomposition chamber may travel to the terrestrial chamber through the straw, and decomposing material may go into the aquatic chamber via the holes in the cap. In addition, water "rained" through Bottle F can cycle throughout the whole column. The oxygen produced by the plants can also cycle throughout the whole column via the straw and holes.

An electric drill can be used to make the cap holes for the three chamber bottle tops. Prior to the lab, the teacher can use a larger drill bit to drill the large hole in one bottle cap, where the straw is inserted. However, students can drill the smaller cap holes during class time using a smaller drill bit. A piece of wood should be placed under the caps when drilling to prevent the drill

FIGURE 1

1A: Materials the teacher supplies.

- Sand
- Packing tape
- Worms
- Water dechlorinizer
- Guppies
- Potting soil
- Seeds (e.g., radishes, lettuce) or small plant such as ivy
- Measuring cups
- Scale
- Graduated cylinders
- Electric drill and drill bits (or a hand drill)
- Fruit flies
- Snail(s) for aquatic chamber
- Aquatic plants (e.g., duckweed)
- Straws

1B: Materials students bring from home.

- Five 2L soda bottles
- Leaves
- Grass
- Banana peel
- Apple core

1C: Optional materials students may choose to use in their columns.

- More aquatic animals (e.g., guppies, shrimp, snails, fiddler crabs)
- Algae or other aquatic plants
- Aquarium rock
- Soil from their own yard
- More insects (ants, crickets, mealworms)
- More terrestrial animals (e. g., lizard, frog, toad, snails)
- Potato

FIGURE 2

Earth System Science Column assembly and observation instructions.

1. Gather all materials (Figure 1).
2. See Figure 4 for cutting and bottle assembly instructions.
3. Record what you put in each chamber and how much (measured or weighed) while assembling your column. Also, take notes on how you assembled your column so you can write instructions for other scientists who want to duplicate your work in order to compare results.
   - Aquatic chamber must include substrate material [e.g., sand/gravel/aquarium rock, one guppy, and aquatic plant(s)]. You may add other organisms or abiotic factors.
   - Terrestrial chamber must include soil (e.g., potting soil or soil from your home) and seeds or plants. You may add other organisms or abiotic factors.
   - Decomposition chamber must include leaf/grass material, potting soil, fruit flies or other animal(s), a piece of fruit (e.g., apple or banana), or a piece of potato. NOTE: Do not include lettuce!
4. Add precipitation to the Earth System Science Column once it is assembled. (Be sure to measure and record your "rain" volume.) Throughout the data collection period, you may add precipitation, but again be sure to record the dates and quantity.
5. Look for changes in each chamber and collect data three times a week. Record your data.
   - You will be given the first 15 minutes of the class period to collect your data. If you need more time, you will need to come in before school, during a free period, at lunch, or after school.
   - You may use the provided data collection table or create one of your own.
6. Complete the following tasks once you have assembled your chamber:
   - Write detailed instructions for the Earth System Science Column assembly;
   - Create a list of biotic and abiotic factors;
   - Draw a diagram of the column;
   - On your diagram be sure to label each chamber and the contents within each chamber. Also identify the location of bottle caps and hole arrangement, presence of straw, and all other details.

from damaging the lab bench. Students should wear safety goggles, and the teacher should monitor students when they are using the drills. A hand drill can also be used to minimize cost and to reduce safety concerns.

Students add sand to the lowest section of their column, which acts as ballast and anchors the aquatic plants. Students then add tap water to the section (allowing the water an opportunity to reach room temperature before the next day). Students measure and record the amount of sand, water, and other ingredients added to their column. These measurements—which can be made with a scale, measuring cup, or graduated cylinder—will help students when they write up the procedures later in the project.

On the second day, students are given the assembly diagram shown in Figure 6 (p. 35). The teacher should have soil, fish, snails, worms, and fruit flies readily available so students can begin adding the remaining ingredients to their columns (Figure 1A). Students add the required ingredients (Figure 1B) and also any optional materials (Figure 1C) that they brought to class. Students (three to four per team) decide on additional materials and organisms to incorporate into their column based on what they have already learned in their Earth science lessons. The teacher guides student inquiry by asking questions about student choices, such as: "How many fish do you think can live in less than a liter of water?" and "Where do the fish get oxygen from?"

Once the bottles are assembled, three separate chambers will exist—terrestrial, decomposition, and aquatic (Figure 6). Students measure and record the amount of abiotic materials and the organisms (biotic) added to their column. Once the column is filled, students measure out some water with a graduated cylinder and pour tap water (precipitation) to the topmost chamber of their column (Figure 6). At this point students should have already discussed the water cycle and understand that as a cycle it is in a closed system like the Earth, and always working with the same amount of water. This value is recorded in student data tables. After the assembly is complete, the columns should be placed near a window. The columns are self-supporting owing to the weight of the sand and water in the bottommost aquatic chamber.

After assembling their columns, students write up the following:

- Title;
- Purpose;
- Three hypotheses (one for each chamber);
- Materials list;
- Procedure; and
- Labeled diagram.

The guidelines in Figure 3 are given to students in their information packet. This part of the assignment is usually due no more than one week after building the column. This time frame allows students to record the procedure while it is still fresh in their minds.

FIGURE 3

Guidelines for the first written part of the project.

Title:

Purpose:

Hypothesis for each chamber:

1. Terrestrial chamber:
2. Decomposition chamber:
3. Aquatic chamber:

Procedure and materials:

(Detailed instructions for Earth System Science Column assembly)

1. Instructions should be in a logical sequence.
2. For the assembly of the bottles you may write "the bottles were cut and assembled according to the instructions provided."
3. Someone should be able to set up the exact same column you did if they followed your instructions.
4. Instructions should be concise and yet provide specific details regarding the materials and quantities used. Some things to consider include:
   - Contents and quantity in the aquatic chamber
   - Contents and quantity in the decomposition chamber
   - Contents and quantity in the terrestrial chamber

HINT: Try writing out the instructions and then run a mock setup with someone who hasn't done this project. Discover any changes you need to make and revise them before you turn in this portion of the assignment.

Labeled diagram of Earth System Science Column:

1. See diagram samples.
2. Diagram has a title which tells the reader what the drawing is.
3. Diagram reveals setup of column.
   - Bottle arrangement
   - Location of straw, etc.
   - Hole arrangement in bottle caps
4. Labels for key features.
   - Each chamber
   - Contents within each chamber

Addressing the Standards.

The Earth System Science Project addresses the following *National Science Education Standards*:

- The ability and understanding of scientific inquiry (NRC 1996, p. 105);
- The origin and evolution of the Earth system (NRC 1996, p. 107);
- Energy in the Earth system (NRC 1996, p. 107); and
- Geochemical cycles (NRC 1996, p. 107).

In addition, "Systems, Order, and Organization" constitutes one of the Unifying Concepts of Science as defined by the *Standards*. The Earth System Science Project enables students to investigate systems and the interaction between the geosphere, hydrosphere, atmosphere, and biosphere. The interaction of the Sun and the cycling of water are also incorporated in the project (NRC 1996, p. 116).

Collecting data

Students collect data on the third day of the project. The teacher should provide Petri dishes, syringes, thermometers, pH charts, pH paper, and water quality test strips. The test strips—readily available from scientific suppliers and pool supply stores—can be used to measure total chlorine, free chlorine, total hardness, total alkalinity, and pH. These test strips are an effective way to get some quantitative data inexpensively. Students should check for agreement in the pH reading by also using the pH paper.

The column comes apart easily between the top of the aquatic chamber and the decomposition chamber. After separating the column, students check the water temperature by inserting a thermometer and also remove a little bit of water with the syringe to obtain water quality with the test strips.

Students also record observations concerning both the abiotic and biotic factors in a data collection chart. Students use this chart to record data approximately three times a week for three weeks. The data collection chart is handed in at the conclusion of the project. Typically after one day, the total and free chlorine readings are zero (these readings only need to be checked when tap water is used). The other readings, however, change depending on the column's ingredients.

The data collection leads students to investigate the results of their data since each column is different. The data also supports the students' answers to guided inquiry questions. Project-grading guidelines are designed to help students to monitor their project and keep track of due dates.

Concluding activities

After the column is built and as the data collection continues, other activities in the curriculum can be incorporated. For example, acid rain activities, water purification laboratories, and food chain activities can be addressed and applied to what students observe in their columns. This project is easily woven into a unit on the

FIGURE 4

Cutting and assembling the bottles.

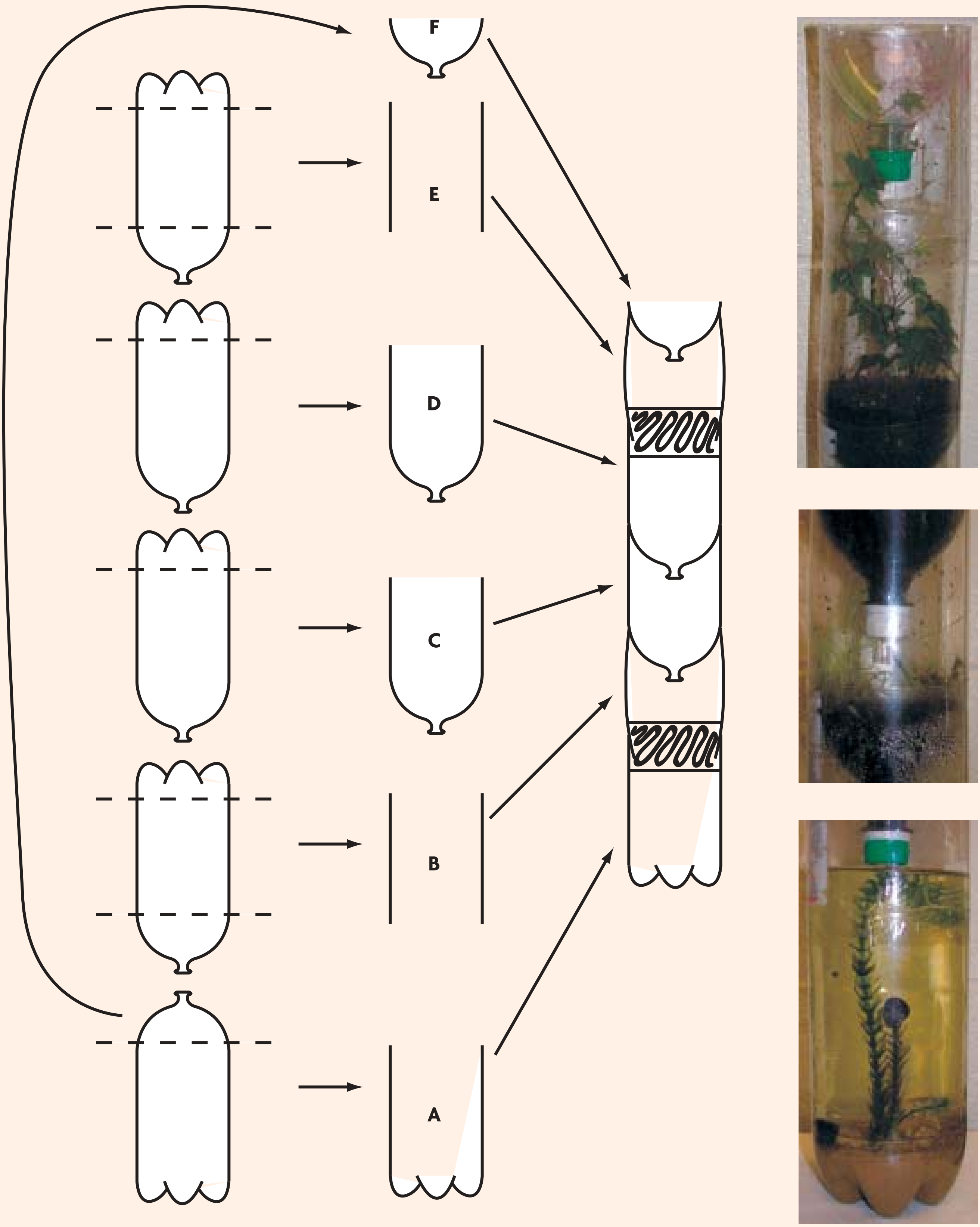

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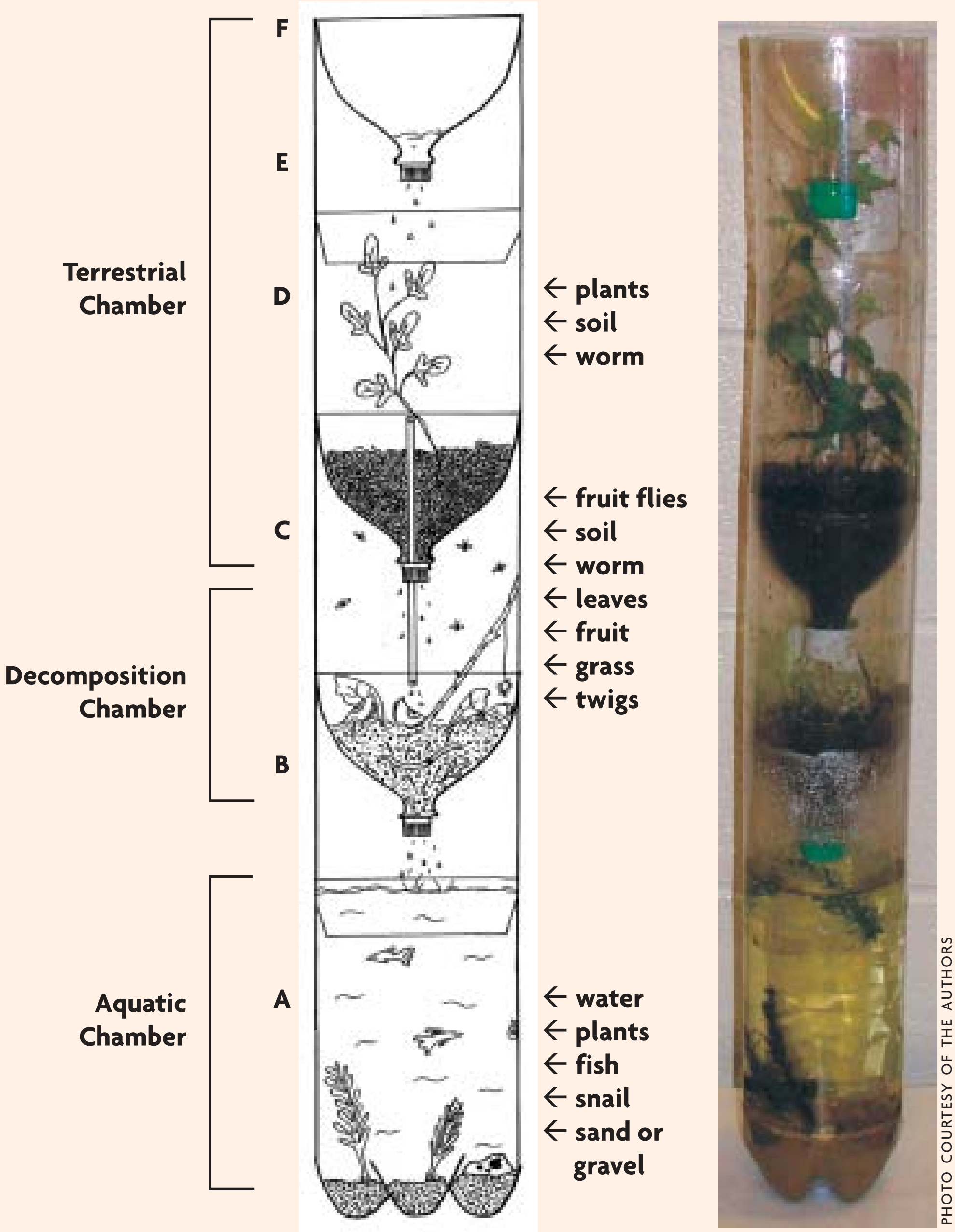
FIGURE 6

Assembly diagram for the Earth System Science column.



hydrosphere and can be used to explore, explain, and extend concepts that are traditionally focused on during the hydrosphere unit. The project concludes with questions that incorporate several Earth science and biological concepts.

The Earth System Science Column is a great project to generate enthusiasm in students, parents, and administrators. Team and class discussions are often generated as to why the columns display different features. For instance, "Why are all the fish in one column dead, while another column has healthy fish that have reproduced?" The inherent variation designed into this project allows students to observe different outcomes and interactions within one type of system—the Earth. ■

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References

Ingram, M. 1993. *Bottle Biology*. Dubuque, Iowa: Kendall/Hunt Publishing Company.

Jager, P. 1993. Bottle biology. *Australian Science Teachers Journal* 39(3): 53–56.

National Research Council (NRC). 1996. *National Science Education Standards*. Washington, D.C.: National Academy Press.

Ochs, V.D., and M.R. Brock. 1975. Bottle biology. *Science and Children* 13(2): 15–17.

The Bottle Biology Project, Department of Plant Pathology, College of Agricultural and Life Sciences, University of Wisconsin-Madison. 1995. Bottle biology. *CSTA Journal* (Winter): 31–35.

Taylor, F., and M. Hebrank. 1995. Pick up that leaf litter. In *Biology on a Shoestring,* 169–184, 225–229. Baltimore: National Association of Biology Teachers.

Wisconsin Fast Plants. 1991. *EcoColumn.* University of Wisconsin-Madison, College of Agricultural and Life Sciences, Department of Plant Pathology. *www.fastplants.org/bottle_biology/pdf/ecocol.pdf.*