Chapter 16

Bringing the Laboratory into the Lecture Hall

Ruth E. Beattie

T. H. Morgan School of Biological Sciences
University of Kentucky
Lexington, KY 40506
Telephone: 859-257-7647
Fax: 859-257-1717
email: rebeat1@pop.uky.edu

Ruth E. Beattie is an Assistant Professor of Biology at the University of Kentucky. She received a BA and a MSc in Biochemistry from Trinity College Dublin, Ireland, and a PhD in Biochemistry from Queen's University Belfast, N. Ireland. She completed two postdoctoral fellowships at the Hipple Cancer Research Center and at Wright State University in Dayton, Ohio. She then taught for four years at Ball State University, Muncie, Indiana. In the Fall of 1995, Dr. Beattie joined the faculty at the University of Kentucky as an instructional specialist, where her primary responsibility is teaching large enrollment freshman level biology classes. Dr. Beattie has developed a variety of innovative classroom activities, which have been successfully implemented in these large classes.

Reprinted From: Beattie, R. E.. 2000. Bringing the laboratory into the lecture hall. Pages 279-294, *in* Tested studies for laboratory teaching, Volume 22 (S. J. Karcher, Editor). Proceedings of the 22nd Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 489 pages.

Contents

Background

Bio 102, Human Ecology, is a non-majors biology course. This course fulfills part of the two-course natural sciences requirement of the university's general education requirement. The course examines the interrelationships of humans with the environment and deals with such topics as acid rain, rainforest destruction, soil and water pollution, the hole in the ozone layer, and world population growth.

The students in this course come from non-science disciplines within the university and are at various stages of their academic careers. Approximately 40% are freshmen, 34% are sophomores and the remaining 26% are juniors and seniors. Many of these students have not taken a biology course since their junior year in high school. From classroom observations it is obvious that many of these students are very uncomfortable with science.

This course is a lecture-only course with an enrollment of 300 students per section. The course does not have a laboratory component and so some students can graduate without ever having taken a science laboratory course.

Large lecture-only courses present some major challenges for the instructor. Teaching in large enrollment classes has traditionally been instructor-directed formal lecturing. Unfortunately this didactic approach to teaching leads to little or no student involvement in the learning process. I use a variety of teaching strategies that encourage active student participation. These strategies move from a didactic learning to a student-directed inquiry / experiential learning format. This allows me to present material in such a way as to address the different learning styles of the students. In an effort to provide students with active learning and some laboratory experiences, I have developed a number of classroom experiences, which I have successfully incorporated into this non-majors biology course.

Activity I. Soil Testing

Introduction

One of the units in the Human Ecology course focuses on soil erosion. This unit begins with a discussion of the properties, function, and composition of soil. This information can very easily be presented in a lecture format but, from experience, I have found that student retention of this course material is low. Instead of sitting passively in the lecture hall, the students conduct a soil survey of the state. Students collect soil samples from around the state of Kentucky. The students, in groups of 8 – 10, then test these samples for nitrogen, potassium, phosphate, and pH (using commercially available soil test kits). They also determine the relative fertility of the soil samples, and conduct an animal and microbial inventory of the soil samples. This activity is used to introduce the students to the soil erosion unit. During later class periods, the results obtained from the soil tests are used as a basis for the lecture. The students use their results to hypothesize on the relationship between the levels of chemicals and the relative fertility of the soil. Each group shares their results with the rest of the class. Additionally, the students are able to relate this information to the geographical / geological make-up of the state.

It should be noted that this activity is carried out with 300 students in a lecture hall during a 50-minute class period with the assistance of only one teaching assistant. The logistics of presenting a "lab" experience to 300+ students in a lecture hall presents some major challenges. Detailed organization of the activity, comprehensive handouts, and clear instructions are crucial to the success of this type of activity. Despite these challenges, this type of activity is very successful in terms of enhancing student learning and participation in the course. The cooperation of the students, and their willingness to sit on the floor and in the aisles has been crucial to these successes. Student participation is so active during these class periods that only minimal input from the instructor is required. The students have been very enthusiastic about and receptive to this type of activity. Evaluations indicate that the majority of the students enjoyed and learned from this experience.

Timeline for Activity (Begins on Day 1 of the Soil Erosion Unit)

Day 1 (Friday) (Do not need a whole class period – just the last 30 minutes.)

- Introduce the activity – give out handouts
- Break students into groups of 8 – 10 (Students self-select their groups)
- Identify one student in each group, who will be responsible for collecting the soil sample. I introduce this activity on a Friday so that students can collect a soil sample when they go home for the weekend. The student who will be travelling the greatest distance from the university is usually delegated to collect the sample.
- Explain the procedure for preparing the soil sample for class on Monday. (student handout)
- Give out soil collecting supplies to the student collecting a sample.

Day 2 (Monday)

- Introduce the day's activities to students. Give out necessary instructions.
- Students conduct tests for nitrogen, potassium, phosphate, and pH.
- Students set up the relative fertility test.
- Students streak a nutrient agar plate with some of their sample.
- Students microscopically and macroscopically examine their soil sample.

Day 3 (Wednesday)

- Students examine growth on nutrient agar plates. Allow about 15 minutes of class time for this.

- Spend the rest of the class period discussing the properties of soil and the importance of the various minerals and chemicals in an interactive lecture format.

Day 4 (Friday)

- Students record the amount of growth from their relative fertility growth experiment. Students share their results with several other groups and draw conclusions. If seeds have not sprouted sufficiently, delay this activity until Monday.
- Students work in groups and complete the questions on the handout. One copy of the completed handout is turned in at the end of the class period for grading. This assignment is a required graded assignment for all students in the class. The information recorded in these submissions is used in subsequent lectures, which focus on soil erosion.

Grading of group project

The points (30) each student can earn in this project are divided into categories:

(a) Individual attendance points (2 days x 5 points/day)
(b) Finished group product (8 points)
(c) Individual contribution of each student (12 points). Each group fills in a form that documents the individual contribution of each student in the group.

Materials

1 student handout per person plus one extra for each group. The extra copy is the copy that will be submitted by the group.

Soil Collecting Supplies for Day 1 (1 set per group) In order to minimize the cost of this activity I mostly use supplies that can be purchased in the grocery store or a garden center.

- 2 8oz-Ball™ jelly jars or equivalent. I use the wide-mouthed jelly jars as it minimizes spills in the lecture hall. The jelly jars are also very durable. One of these jars should be filled with 4 oz of water. This eliminates one potential variable -- that of different water sources -- in the chemical tests.
- I teaspoon (plastic).
- Small Ziplock™ bag (1 pint size)
- Everything packaged into a larger Ziplock™ bag.

Supplies for Day 2

Per group in a Ziplock™ bag:

- 1 or 2 Petri dish (does not have to be sterile)
- 1 plastic spoon
- 1 sterile swab
- 4 x 20-mL glass vials with caps. With a permanent marker draw a line at the 10 ml volume level on the vial.
- 1 test capsule for each of the chemical tests. Place these in one of the vials and cap. The test capsules are found in the RapidTest Soil Test Kits found in most garden centers and Wal-Mart, K-Mart, etc. Get the test kit that has 4 x 10 capsules (10 for N, 10 for K, 10 for P and 10 for pH). These cost about $15.

NOTE: The test capsules come in a container that includes a reaction chamber. If you have a small number of groups in your class and enough containers for each group (or enough time to stagger the use of the reaction chambers), the students can conduct the tests in the reaction chambers. Because I have a large number of groups and not enough containers for each group, I have the students conduct the tests in the 20 ml glass vials. I remove the color charts from the reaction chambers and attach them to a key ring. This makes it easier to circulate the color charts between groups.

- 3 film cases (do not need caps). I get cases from the local One-Hour Photo.
- 7 small self-adhesive labels. (I cut file folder labels into 4)
- 1 nutrient agar plate

General Equipment

- Color test cards from the RapidTest Soil test Kits
- 3 varieties of sprouting seeds (The best value is the sprouting seeds available from health food stores.) I use radish, cabbage, and alfalfa. Sprouting beans also work well.
- Distilled water in wash bottles (200 – 300 ml volume total)
- 3 plastic basins for waste (label one: used vials, label a second one: used swabs, label the third one: Ziplock™ bags and contents except for vials, soil samples in Ziplock™ bags)
- Several trash bags
- 2 plastic trays to put seeds on.
- 3 – 5 microscopes
- Scotch™ tape
- Lots of paper towels
- Permanent marker (to mark nutrient agar plates)
- Hand lenses

All of these supplies should be placed on a cart and wheeled into the lecture hall at the beginning of the class period.

Supplies for Day 3

- The inoculated nutrient agar plates from Day 2
- Trash bags
- Hand lenses (one per group)

Supplies for Day 4

- Rulers (plastic 6 inch): one per group
- Lots of trash bags
- Lots of paper towels

Notes for Instructor

Day 1

- Prepare the soil collecting supplies in advance of class.
- Prepare and duplicate handouts (see Appendix A).
- Bring a map of the state to class so students can mark where their soil sample was collected.
- During the class period: Introduce the activity and describe the procedure for preparing the soil extract. (See student handout found in Appendix A). Hand out supplies after students have formed groups and have identified their “soil collector”.

Day 2

- Prepare supplies as listed above.
- As soon as you can get into the classroom, set up microscopes around the room. The location of microscopes will depend on where power outlets are located.
- Place communal supplies on the instructor’s desk and/ or leave them on the cart.
- Lay out the labeled trays and basins.
- Once class begins: Give out instructions on how the activity will be conducted; hand out Ziplock™ bags of supplies; demonstrate how to prepare a wet mount of a soil sample and how to streak a nutrient agar plate; demonstrate (briefly) how to use a microscope; explain how chemical tests will be conducted (see RapidTest Soil test Kit instructions);
- Stand back and let the students work on the activity.
- Ten minutes before the end of class: Remind students about clean up procedures. Relative fertility test experiments should be placed on appropriate trays. Nutrient agar plates should be taped shut and placed on a tray. All other materials should be placed in appropriate basins. The soil collecting supplies given out during the previous class period should also be collected at this time.
- At the end of the class period: Load all supplies and microscopes onto the cart and exit the classroom.
- At the University of Kentucky, there is a ten-minute break between classes. It is possible to setup and clean up this activity within that time. It helps if you can have the assistance of at least one teaching assistant.
- After class: Place the trays with the seeds in a bright (safe) place. Water seed trays all equally. Incubate the nutrient agar plates at room temp.

Day 3

- Bring the nutrient agar plates to class. Groups should claim their plates. Have the students macroscopically examine the growth that will have appeared on the plate. DO NOT PERMIT THE STUDENTS TO OPEN THE PLATES. DOUBLE CHECK THAT ALL PLATES ARE TAPED SHUT BEFORE HANDING THEM OUT TO STUDENTS. Direct the students in their examination of the plates. Have them count the number of different types of growth on the plate. Discuss the roles of bacteria and fungi in the soil. (Students have studied soil ecosystems earlier in the semester.)

- Collect these plates, place them in a trash bag, and later dispose of them appropriately.
- Spend the rest of the class period in interactive lecture, discussing the properties of soil, etc.

Day 4

- Bring the sprouting seeds to class and hand them out to students.
- Students then document the number of germinating seeds and the length of the roots and shoots of their seedlings compared to other groups with different soil samples. Students draw conclusions based on their observations.
- The best way to document this information is to have the students carefully empty the film cases onto a paper towel.
- Collect up all film cases, soil, paper towels, etc.
- Spend the rest of the class moving from group to group as students complete the questions on the handout.
- Collect one completed handout from each group at the end of the class period.

Activity II. Water Pollution Testing Activity

Introduction

Another unit in this Human Ecology course focuses on the problems associated with water pollution. In order to sensitize students to the impact of even small amounts of pollutants on water ecosystems, I begin this unit with this water pollution activity. This activity is from *Using Fast Plants and Bottle Biology in the Classroom,* published by the National Association of Biology Teachers, 1994, ISBN #0-941212-17-3. In this activity, students test the effects of common household fluids and waste on water quality.

Timeline

Day 1

- Introduce the activity: include a review of scientific method and experimental design.
- Students set up artificial ponds and add pollutants.
- Ponds "incubate" for 1 week.

Day 2 – One Week later:

- Students examine the pond weed; check the number of surviving plants, the size and apparent health of plants in their experimental pond compared to the control pond.
- Students work in groups to complete questions on the handout.

Materials

Day 1

- 4 1-liter or 2-liter plastic bottles per group. I have the students bring these. To ensure a large enough supply for the activity have students bring bottles for several class periods before the project starts. You may need to switch bottles to make sure each group is working with 4 of the same sized and colored bottles.

- Scissors – at least one pair per group. Students supply their own scissors.
- 1 pint-sized measuring cup or equivalent per group. I use pint-sized jelly jars (from the soil testing activity).
- 2 plastic spoons per group
- 4 small self-adhesive labels per group.
- Lots of gallon jugs of water – need 4 pints per group.
- Pond weed (*Lemna minor)* approx. 80 plants per group – store plants in two or three small shallow basins. (I collect my pond weed from the fish tanks and aquaria maintained in the school. You can also collect this pond weed from small lakes and ponds in the spring/summer/earl fall months.)
- Lots of paper towels
- Several trash bags
- Pollutants: I place these in pint-sized jelly jars and place a spoon or dropper in each. The pollutants are less likely to be spilled if they are in wide-mouthed jars. Jelly jars can be capped, which prevents spillage to and from the lecture hall. Place the jelly jars on plastic trays to contain any spillage should it occur.
    - Antifreeze
    - Used car oil
    - Salt
    - Toothpaste
    - Coffee grounds
    - Shampoo
    - Clorox™ bleach
    - Fertilizer
    - Coke or equivalent acidic soda
    - Soap shavings (both biodegradable and non-biodegradable)
    - Anything else of your choice

All supplies should be placed on a cart and wheeled into the lecture hall.

Notes for Instructors

Day 1

- Prepare and duplicate the student handout (see Appendix B)
- Load all supplies above onto a cart. Store plastic bottles in plastic bags.
- As soon as you can get into the classroom, lay out the pollutants and pondweed.
- When class begins: Introduce the activity, demonstrate how students will make the artificial ponds; review scientific method and experimental design with students emphasizing the importance of controlling all variables except for the experimental variable.
- Stand back and let the students begin the activity.
- At the end of class have students either carry their ponds to wherever the ponds will sit for a week or have them placed on a cart.

- Place pollutants and other supplies on a cart and exit the classroom.
- Place ponds in a bright, airy space where they won't be disturbed.

Day 2 – One Week later

- Bring ponds to class.
- Hand out ponds to students and instruct them to begin their observations.
- At the end of class, collect all ponds. Dispose of ponds appropriately. I filter out the pondweed and then flush the fluid down the sink EXCEPT for those ponds containing oil or antifreeze. These are disposed of according to accepted university safety procedures.

Appendix A Soil Testing Student Handout

Soil Testing

During the next few class periods we are going to test soil samples from around the state of Kentucky. We will be testing these samples for pH, nitrogen, potassium, and phosphate. In addition we will compare the relative fertility of different soil samples, and will carry out an inventory of the animal and microbial life found in soil samples. The class will be divided into groups of 10 students with each group testing one sample. One student from each group will be responsible for collecting the test sample. To ensure a wide coverage of the state; please mark on the state map the location where the sample will be collected. We want to minimize duplicate sample areas.

GROUP NAME:

Group Members:	1.	6.
	2.	7.
	3.	8.
	4.	9.
	5.	10.

Name of person collecting soil sample:

Location of soil sample:

How to prepare the soil sample for testing:

Materials needed:
- Soil sample – 15 teaspoons in volume
- Teaspoon
- 2 jelly jars provided by instructor (1 jar empty, 1 jar with 200 ml water)
- Ziplock™ bag for the soil sample.

The student who will be collecting the soil sample must carry out this procedure at least 24 hrs before the class period. Add three heaping teaspoons of soil to the jelly jar that contains water. Cap the jar and shake vigorously. Allow the mixture to settle (depending on the soil sample this may take from 1 to 24 hours). Decant the clear liquid into the second (empty) jar and bring it to class. This is the soil extract. Try not to disturb the settled material when you decant the liquid into the second jar. Keep the remaining soil sample in the Ziplock™ bag and bring it to class also.

Date sample was collected:

Weather conditions and temperature when sample was collected:

Appearance of soil sample (color, texture, etc):

Chemical Test Prodecures

Get a Ziplock™ bag of supplies from the instructor. Remove the four glass vials. Take the 4 capsules out of the vial. Label the vials 1 through 4 using the labels provided. Fill each vial to the black line with the soil extract. To vial #1 add the contents of the pH test capsule (the green capsule). Do not drop the capsule directly into the soil extract, instead hold it between your fingers and gently twist and pull the two halves of the capsule apart. Empty the contents into the vial. To vial #2 add the contents of the nitrogen (purple) capsule. To vial #3 add the contents of the potassium (orange) capsule and to vial #4 add the contents of the capsule for phosphate (blue). Cap the vials and shake the contents vigorously. Allow the vials to sit for 10 minutes before interpreting the results. To interpret the results, compare the color intensity of your test sample with the provided color charts. Record the results on the data table. When these tests are complete, place the vials (with liquid) into the appropriate waste basin.

Data Table

	pH	**Nitrogen**	**Potassium**	**Phosphate**
Color of solution				
Results				

Fertility Testing

Take the three film cases from the Ziplock™ bag. Label the cases 1 through 3 and also include your group name. Fill each film case half full with soil. Moisten the soil sample with the water provided. Three different varieties of seed have been provided for testing. To each film case add 10 seeds of one variety (3 film cases – three different varieties). Place the film cases on the tray on the instructor's desk. After 5 days examine the resulting growth and compare your results with some of the other groups.

Results Table

	Seed Type #1	Seed Type #2	Seed Type #3
# of seeds planted			
# of seeds germinated			
% germination rate			
Average length of germinated seedlings (from root tip to shoot tip)			
Average length of roots			
Other observations			

Results from other groups:

Conclusions that can be drawn from these comparisons:

After all observations are completed, place the film cases in the provided basins for disposal.

Animal and Microbial Inventory

Spread one teaspoon of soil in the Petri dish. Examine the sample for animal life. Hand lenses are available on the instructor's desk. Prepare a wet mount of your soil sample and microscopically examine it. Record the results of your examinations.

Macroscopic observations	Microscopic Observations

Each group will inoculate a nutrient agar plate with their soil sample. The course instructor will demonstrate this technique. After you have inoculated your plate, tape the two halves together using the tape on the instructor's desk and label it with your group name and the date. Then place the plate on the appropriately labeled tray. The plates will be incubated at room temperature until the next class period.

Second Class Period: Examine the resulting bacterial and fungal growth on the plate. DO NOT OPEN THE PLATE OR TOUCH ANY OF THE GROWTH. Record the results of your observations below. Compare your results with another group. When you have completed your observations place the plate in the trash bag provided for correct disposal.

Observations:

Analysis of Results

Describe the area (geography, geology, land use, predominant vegetation type, and type of farming) from which the sample was collected.

What conclusions can you draw about the geography of the area and its fertility?

Are there any connections between fertility and high levels of nitrogen, potassium and phosphate?

What was the pH of your soil sample?

Is acid rain a problem in this area?

If yes, what is the source of the acid rain?

Did your soil sample have a high pH?

If yes, was the area recently treated with lime?

At what pH do each of the types of seeds grow best? You may have to check with a local garden center for this information.

Seed Type #1
Seed Type #2
Seed Type #3

Do your germination rates reflect these pH preferences?

Do some of the soil samples have large numbers of animals and/or bacteria present compared to others?

If so, is there a relationship between fertility and animal life?

Does the soil sample contain large amounts of decaying organic matter?

Was there evidence of pollution in the area from which the sample was collected?

If so, how might this pollution have affected the soil?

Was there evidence of soil erosion?

List four different environmental problems that could impact strongly on this area.

How could you reduce or eliminate such environmental impacts?

Appendix B   Water Pollution Student Handout

Water Pollution Testing

During the next few class periods we will be examining the effects of household fluids on water quality. The class will be divided into groups of 8 - 10 students. Each group will carry out their own pollution experiment and will then share their findings with the rest of the class.

Group members:		
	1.	6.
	2.	7.
	3.	8.
	4.	9.
	5.	10.

The pollution experiment will be carried out using artificial "ponds" manufactured from 1 or 2 liter plastic bottles. To make a pond, cut a plastic bottle as shown in the diagram below (Figure 16.1a). Keep both pieces of the cut bottle. The caps, which are not needed, should be discarded in the labeled basin.

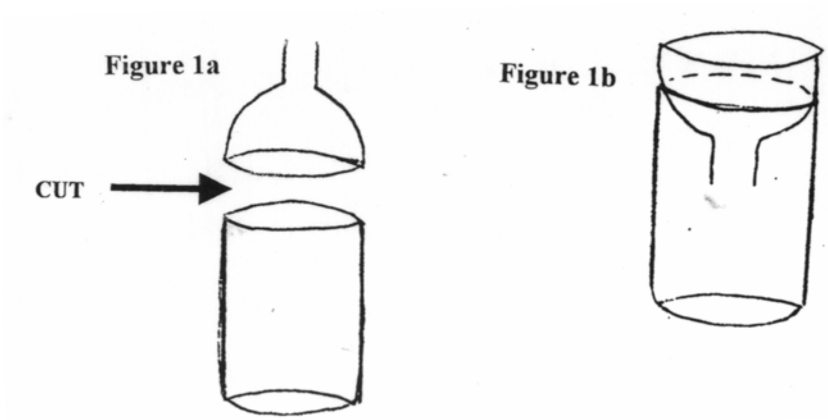

Figure 16.1. Making a Pond.

Label the ponds 1 through 4. Add 1 Ball™ jar full of water to each pond. Pond #1 will be your control pond. To this pond add 20 duckweed plants. Use your spoons to remove the pondweed from the basins. Try to avoid handling the plants so that soap residue on your hands will not be introduced into your ponds accidentally. Cover the pond with the top of your cut bottle. (See Figure 16.1b). The other three ponds will be your experimental ponds. Look at the provided pollutants on the instructor's desk. As a group decide which pollutants you will use. To each pond add a **realistic** amount of the pollutant, using only one pollutant per pond. Or if you wish you can use varying amounts of the same pollutant. Stir the water to ensure the pollutant is evenly distributed through out the pond. Add 20 duckweed plants to each pond and cover as for pond #1. At the end of the class period, designate someone in your group to carry the ponds to the room where they will incubate for one week. Make sure your ponds are labeled with your group name.

Setup Table

	POND #1	POND #2	POND #3	POND #4
Name of pollutant	None - Control Pond			
Amount of pollutant used				
# of plants used				

Results

After one week check the ponds, count the number of surviving plants. Note the size of the experimental plants compared to the control plants and the apparent health of the plants compared to the control plants. Measure the length of the roots. Fill in the data table.

Data Table

	POND #1	POND #2	POND #3	Pond #4
Type and amount of pollutant used	None - Control Pond			
# of surviving plants				
Size of surviving plants compared to control				
Health of plants compared to control				
Length of roots in mm				

Analysis of Results

What pollutants did you use in your experiments?

What is the source of these pollutants?

Are they point source or nonpoint source pollutants?

Did all of the pollutants have a detrimental effect on the duckweed plants?

How would you categorize these pollutants?

How did these pollutants affect the plants? (i.e. did they kill the plants, stunt their growth, or cause abnormal growth?)

Discuss ways in which you and your community might reduce or eliminate water pollution of this type.

Should local governments enact laws to curb this type of pollution?

What problems would be encountered in enforcing these laws?

How could you use the results of experiments such as this to highlight the effects of household fluids on water quality?