Biology Is Outdoors!

A Comprehensive Resource for Studying School Environments

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Introduction

During most of human history, naturalists have studied the living world in the field, with occasional forays to the lab, but in the 20th century, the laboratory has become the scene of biological activity, and most biologists are lab-oriented. Laboratories and their equipment have become increasingly more complex; the findings ever more refined, abstract, and detached from the natural world. Now among professional biologists, only ecologists retain the old outdoor connection, and even many of their studies are done in the lab. The scene has shifted: Now most naturalists are amateurs who enjoy learning about nature as an avocation or form of recreation.

The increasing sophistication of the research creates problems for biology teachers who struggle to keep reasonably up-to-date and who wonder how much of the new and how much of the old they can transmit to their students. Too often youngsters' sense of wonder at the natural world, and curiosity about it, gets lost in the shuffle as events at the molecular level take center stage in biology classes. For many students, molecular biology is not simply incomprehensible; it is positively sapping to the spirit of wonder and curiosity. It is time to return to nature.

Some teachers continue to make use of that reputable old standby, the field trip, but this is often fraught with problems. Teachers are ill-prepared for field work, since their own education emphasized lab studies. The host of scheduling, transportation, and site selection difficulties can discourage the staunchest field-trip advocate. Besides, lurking in the subconscious is a nagging feeling that somehow such an activity really isn't scientific enough. But field study is valid, and it remains the best way to learn about nature and to stay in touch with it.

This book offers, in place of the conventional field trip, investigations into the familiar world of the school grounds. May you find it helpful.

The School Grounds as an Ecosystem

A school environment is so obviously an artificial environment that you may be tempted to dismiss it as a subject for study. Or you may think that only suburban schools, well endowed with grounds, could provide a suitable environment. In fact, though, life is irrepressible and found in any environment, even the most pavement-surrounded urban school. It is a matter of looking for it.

Any ecosystem comprises both the physical aspect of the environment (climate, geology, geography) and the interacting organisms. In an artificial environment, the terrain has been altered for human purposes, accompanied by the loss of most of the native plants and animals (cutting forests to make fields for agricultural purposes and covering open areas with buildings and pavement are the most obvious examples). After such radical alterations, new plants, whether crops or landscaping, are added, further changing the environment for the animals. New animal species, able to live in the new conditions, move in and become established. Before long, a thriving, self-contained community of life exists in this artificial environment. Such a community is well worth investigating.

Unlike the conventional field trip to distant parts, the school grounds are as near as the door. You don't have to worry about procuring extra time, buses, or personnel. Insurance, which concerns administrators, does not constitute a problem, since the school's insurance covers its grounds. Thus the school grounds provide an unusual educational opportunity: they solve organizational problems while providing a unique ecosystem to study.

The Plan of the Book

Science, a way of learning about the world through objective, repeatable investigation, is always on the cutting edge of knowledge. Science is inquiry. That is one of the most important things for students to understand, and inquiry should be one of the major objectives of any science course. While students may not be on the cutting edge of knowledge—though occasionally they are—they should have the opportunity to investigate real topics for which there are no "right answers" in the textbook.

It is in this spirit, and with the conviction that investigation is the best way for students really to understand science, that this book was undertaken. All the investigations are open-ended and adaptable to different locations; portions can be selected to fit your time and educational goals.

The book consists of ten investigations:

1. Physical Setting of the School
2. Plant Life on the School Grounds
3. Health of the School Grounds' Plants
4. Soil Analysis
5. Soil Organisms
6. Opportunistic Species
7. Microenvironments
8. Impact of the School Building on the Environment
9. Impact of People on the Environment
10. Natural Areas

The investigations are organized into the following sections:

Teacher's Section

The opening section, addressed to you, contains material that will help you handle that particular investigation. It begins with background information on the subject for your benefit which you can use to give students preliminary information before they begin the investigation.

Following that is a part titled "Procedure" that explains what sorts of things are to be investigated and how to go about doing so, as well as management suggestions. Needed equipment and its use is also explained in this part, though one investigation (5) has a separate section devoted to equipment.

Lists of supplies for the investigation and pertinent references are found at the end of each Teacher's Section.

In addition, the parts titled "Results" and "Discussion" of some Teacher's Sections help you make full educational use of the investigation. Discussion questions focusing on important aspects of the investigation are included with "Comments" to help you lead class discussion. Investigations without "Comments" have answers that will vary according to procedure and location. All the questions, however, do require students to draw thoughtful conclusions from their data.

Student's Section

This section is written for the student and can be reproduced for your class. It consists primarily of "Directions for Obtaining the Data," a part that closely parallels "Procedure" in the Teacher's Section. There are some differences in phraseology, but the two parts are substantively the same.

The Student's Section also contains Data Sheets. These pages, intended as a common form for recording the investigation's results, are also reproducible.

Finally, suggestions for further investigation called "Spinoff Ideas" are included with some of the investigations (4, 5, 6, 7, 8, 10). They are addressed to the student, can be reproduced, and offer some ideas for **independent research projects.**

Educational Aspects of Investigation

Student investigation is undertaken for one purpose only: its educational benefit. It exists for students, not for the advancement of scientific knowledge. As such, it must provide students with opportunities to pose questions, to devise logical means of answering them, to draw conclusions, and above all to recognize errors they made in procedure or rationale. These are worthwhile skills which will serve all students, whatever paths they choose in life.

In addition, in our scientific and technological society, students should understand how scientific knowledge is acquired. There is no better way for them to do so than by conducting investigations themselves.

In order to insure that education really does happen, and to the best possible extent, you need to be aware of and take into consideration a number of aspects as you begin this venture.

Site

Field studies are always more difficult to manage than ones in the lab; that's one of the reasons teachers tend to avoid them. For youngsters, outdoors means freedom from the confines, physical and mental, of the classroom. It's recess. To get them to approach outdoor study in the proper frame of mind requires preparation and organization on your part.

Planning

After you have decided on the amount of time you wish to devote to this subject, you must familiarize yourself with the area in order to see which particular investigations you can use and how to adapt them to your school's grounds. Of necessity, the wording in this book is general, applicable to the wide variety of school grounds found across the country. This book provides the guidelines, but you have to make them specific for your own situation.

Part of your familiarization must include the organisms. You need not pursue this in depth—identifying species, for example—but you do need to know locations where organisms can be found. The emphasis in these investigations is on higher plants and small organisms, and the latter, though omnipresent, are not easy to discover. It helps if you know which bushes are infested with insects or lichens, where good puddles are found, areas of human impact, and little pockets of nature. That knowledge enables you to plan activities most effectively.

Organization

Organization is of prime importance. You can get away with some deficiencies in planning and familiarity with the area as long as the activity as a whole is organized. The tighter the organization, the more smoothly the investigation will proceed and the better the educational value.

Decide ahead of time how students are going to work—whether individually, in partnerships, in teams, or as a whole class; suggestions are included in the Teacher's Section. In most cases, the investigations are conducted by teams of three or four students. It is preferable for you to assign students to teams. Left to themselves, students will choose to work with their friends, a situation that tends to promote the carnival atmosphere, as well as cliquishness, that you wish to discourage. If you make the assignments, you can avoid team homogeneity, and by changing the teams with each investigation, you force new associations, some of which may develop into friendships. Your selections are also more objective, and the shy or new or different youngster is fully included.

Prepare your students for this activity ahead of time by giving them information on the subject in a way that excites their interest. Your approach makes all the difference: If they catch a feeling of excitement, expectation, and adventure from you, they will be in the right mood for investigation, but if you are flat, disinterested, going through the motions, or apprehensive, your students will not take the activity seriously and will give you all sorts of problems. Other suggestions include giving students a chance to participate in planning, taking their ideas seriously, and being involved yourself in the outdoor activities.

Assign each team its tasks before you go out. Try to plan things so that the teams have about the same work load and that they are busy. One of the best ways to create the working atmosphere that investigation requires is to prevent idleness. Students should be somewhat too busy—not overwhelmed but pushed so they have to keep going. Timing an activity works wonders. So does knowing exactly where to go, what is to be done, and having all the necessary supplies on hand.

When outdoors, monitor activities carefully and be prepared to remove anyone who insists on horsing around, not taking part properly and preventing others from doing so. At the same time, encouraging the strugglers and commenting publicly on work especially well done makes the individual feel noticed and tells the class that you are on top of things. That helps everyone's attitude.

Once the data or materials have been collected outdoors, get your class back to the lab. Don't be persuaded to have a discussion outdoors.

Objectivity

You do want your students to be honest and objective about their procedures and the accuracy of their results. You also want them to enjoy investigating. Once again, your attitude is the key. Your students cannot be as objective or accurate as you might wish—they are only learners, after all. So while you should stress those desirable qualities, you cannot emphasize results, especially "good" ones, too much, or grade on them, since that tends to encourage students to achieve what they think you want, often at the cost of honesty. Subtlety is called for. Reward the effort more than the results.

Data Sheets

Most students simply have no idea of what information is important to an investigation or how to record it. With that in mind, the data sheets were set up to give students a form for recording their results. This has several advantages. With everyone using the

same form, the data are more consistent and comparisons easier to make. It is also easier to evaluate.

The term "data sheets" was chosen deliberately. These are forms for recording data, the same sort used by professional scientists for their data, not the usual workbook fill-in pages. These are real data your students are recording, and as such they should be recorded at the time observations or experiments are done, which will mostly be outdoors. Data sheets are results of the investigation and should be carefully preserved. You need to emphasize these points to your students.

Students should pay attention to the form of the data sheets, since the sheets teach recording skills—something that is useful not only in science courses but also in other contexts where one must record information. To give students the opportunity to devise a recording form, one investigation (9) that is particularly variable does not have a data sheet.

Discussion

In scientific investigations, drawing conclusions and seeing their significance is of great importance; indeed, it is the reason for the investigation in the first place. Scientists typically share their results and their thinking with one another by means of papers and seminars.

This is also true for students. The written report serves a valuable purpose, but too often it is seen only by the teacher and the student who wrote it. Sharing ideas with one another is important, for in doing so a student learns about skepticism, disagreement, conclusions that can't be substantiated, nonconforming results, and intellectual give and take. These worthwhile lessons, important aspects of investigation (and life), are best fostered through discussion.

In most cases, individual students do, and hence focus on, only a part of the investigation. Sharing results enables them to see the whole picture and therefore be better able to understand its significance.

Handling a discussion is a supreme exercise in the teaching art. You have to challenge, encourage, referee, restrain, adjudicate, coach, and stimulate while resisting the urge to leap in and provide the "right" conclusion. A tightrope act if ever there was one! Yet if you manage well, your students will become so absorbed that they'll forget everything else, including you, and the discussion will carry on by itself—often even after class. It's very satisfying to see students startled by the ringing bell!

The purpose of the discussion is to share ideas, not to reach consensus, so don't attempt to have students reach general agreement, and be sure they don't feel uncomfortable about unresolved questions.

Evaluation

Grading of investigations should take all facets into account: performance, data sheets, discussion, and the subjective qualities of attitude, effort, and the attempts to understand and express budding ideas.

Investigation 4

Soil Analysis

Teacher's Section

Soil is an enormously complex ecosystem composed of weathered rock particles, organic materials in various stages of decay, soil organisms, air, and water. Organic materials are broken down to inorganic ones by the organisms and in combination with the rock particles comprise the substances (ions, radicals, and molecules) that collectively are known as soil minerals.

Rocky particles vary in size from clay (particle size less than 0.002 mm diameter) to silt (particle size 0.002 to 0.05 mm diameter) to sand (particle size 0.05 to 2.0 mm). The spaces surrounding the particles are filled with air or water. The size of the particles and their angularity determine the amount of space around them, since tinier particles pack more closely than larger and more irregular ones do. The amount of space determines air- and water-holding capacities. Clay absorbs water readily, with particles and spaces coated, and becomes waterlogged. That reduces or even eliminates the amount of air in clay soil. Sand, on the other hand, has large spaces, holding plenty of air, but since water tends to percolate through the spaces easily, sandy soil has poor water-retaining properties. Neither sand nor clay makes good soil. The best growing soil, loam, contains clay and sand particles in roughly equal amounts, along with about the same amount of organic material, or humus. Humus gives the soil its bulk. It is nutrient-rich, alive with organisms, and spongy, retaining minerals, air, and water in its loose structure.

In order to sustain their lives normally, plants require six macrominerals (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur) and seven microminerals (iron, copper, zinc, molybdenum, cobalt, boron, and manganese). They make up those essential compounds, DNA, RNA, and proteins (both cell structures and enzymes), as well as many other vital compounds such as chlorophyll.

Minerals enter the roots not as solids but as ions dissolved in soil water. Their solubility depends on the pH of the soil water, which in turn is influenced by the chemistry of the specific soil. Each mineral has its own solubility range: an optimal pH range at which it is most soluble, gradually tapering off both above and below that level until it is no longer soluble. All the macrominerals, for example, are insoluble at pH 4 and below.

Actually, the situation is more complicated. Many more minerals are in the soil than plants require, and under the proper conditions these minerals react to form more complex, and usually insoluble, compounds. Molybdenum and iron, for example, react at low pH levels to form an insoluble compound, making both of them unavailable to plants.

The total range of pH values for plant life is 4 to 9, but the species that can live at the extremes are few. They are found, respectively, in peat bogs and alkali deserts, neither of which concern us here. Most garden soils are in the range of 6 to 8 pH, a range

that coincides with optimal solubility of all the vital minerals. Not surprisingly, plants do well under those conditions.

Many North American soils, however, fall in the pH range of 5 to 6. These acid soils are usually treated with lime to raise the pH. As another example of the complexity of soil interactions, many minerals, required or not, are quite soluble at low pH levels. Excesses are absorbed and can easily reach a toxic level in the plant body (another reason why most plants don't thrive when the pH is low). As the pH is raised toward neutrality, the solubility of these minerals decreases, thus eliminating the excess and preventing toxicity. If, however, the pH continues to be raised in order to make some minerals more soluble, then the solubility of other minerals may decrease to the point of deficiency.

Aluminum sulfate is used to lower the pH. As is true with lime, altering the pH affects mineral solubility, sometimes to the point of creating problems.

Different species of plants have different mineral requirements and therefore require different types of soil, but there are some common aspects of plant physiology. Plants absorb all the ions, radicals, and molecules present in soil water whether they are needed or not (size is the only limit). Since plants cannot distinguish beneficial from harmful substances and cannot exclude soil water substances below a certain size, mineral concentrations in plants can reach toxic levels. Minerals toxic to plants include: aluminum (the most common mineral), arsenic, heavy metals (lead and mercury, particularly), and essential microminerals in high concentrations. Toxicity results from mineral imbalance.

Procedure

Divide your class into teams of about three members each and assign each a site, using the same sites as in Investigation 2 (foundation planting beds, walkway borders, near free-standing trees or shrubs, and lawn) and adding paths that cut across the lawn. In order to examine the soils so that comparisons can be made among different sites, each team should do all the tests. The results are then recorded on the data sheets and shared with the rest of the class (see "Results").

The tests are done on soil below the surface. This necessitates digging down several inches, into the root zone. Digging on the lawn means removing a clump of sod about 6 inches in diameter. It should be placed in the shade, roots down, while the investigation is going on and then replaced, tamping it down carefully.

1. Preliminary Examination

Students should examine the soil by looking closely at a handful of it. The different components are quite apparent. Minerals are light-colored, rocky, and angular. Humus is dark and contains fragments of twigs or other recognizable bits of biological material.

a. Composition

Students determine, subjectively, the relative amounts of minerals and humus present.

b. Friability

This is an informal gardener's test to determine when soil is in good planting condition. Pick up a handful of soil and squeeze it tightly. When the pressure is released, good friable soil slowly crumbles apart, but wet soil holds together in a ball and dry or sandy soil simply runs through your fingers.

2. Mineral Content

The relative proportion of the different minerals can be determined quite easily. If soil is mixed with water and then allowed to stand, the particles will settle out in layers according to weight. Sand particles are the heaviest and settle out quickly, while lighter-weight silt and clay particles take much longer. They gradually settle to form two layers above the sand, with silt in the middle and clay on top. However, the settling of these fine particles, particularly clay (which is held in suspension by the motion of water molecules), is too slow for classroom purposes. A wetting agent, such as is present in liquid detergents or water softeners, speeds up the process by coating the particles and thus altering their natural behavior.

Provide each team with a wide-mouthed quart jar (mayonnaise ones are good). Students add water until the jars are slightly over half full, then put in one to two teaspoonfuls of detergent, and then fill the jar almost full of soil. Next, students screw the cap on tightly, shake the jar vigorously to mix the contents thoroughly, and then let the jar stand.

Settling begins almost at once, and the layers gradually appear as the water clears.

Separation involves humus particles as well as the inorganic minerals. The former are scattered in the different layers according to their weight, and probably some of the lightest will continue to float even after the minerals have settled. Mineral separation makes it possible to identify the different minerals by their behavior and appearance. If you wish to examine them more closely, you can insert a pipette into the layer, bulb closed, then open it to extract a sample. The samples can be examined microscopically.

The jars, labeled with the site they came from, can be kept for reference throughout the study.

3. Water-Holding Capacity

One of the most important biological properties of soil is its capacity to retain water. There are several ways to determine this, but usually what is measured is the opposite: drainage. All soils retain water in the spaces around particles, and in all soils excess water drains downward, though the speed with which it does so varies greatly. Humus, which has a large surface area, retains water well, and the more of it there is, the better the water-holding capacity. Little drains off. Sandy soils, at the opposite extreme, are so porous that water practically flows through them unimpeded. Thus the easiest way to determine water-holding capacity is to measure the speed of drainage (that is the "perk test" done on housing sites).

Traditionally, the test consists of pushing a coffee can, both ends removed, into the soil, filling it with water, and timing how long it takes the water to drain out—a procedure fraught with obvious hazards.

Instead, use a PVC coupler or a length of PVC tubing about four inches in diameter. The coupler, a smooth, finished piece, is about four inches long. Tubing can be cut to any length (about six inches is good), but after cutting you do have to make sure the ends are smooth. It doesn't matter which piece of PVC you use, nor the exact size, but the teams should all have identical material so that results can be compared.

Students stand the tube on end on the ground and push it about two inches down into the soil. That is easily done in cultivated soil, but may be next to impossible on lawn or packed paths. In those cases, have students cut a circle slightly larger than the outside of the tube with the trowel and set the tube in the cut. It should be firmly in place. If not, students should pack some soil around the outside but leave the soil inside undisturbed. Students fill their tube with water and record the time when it was poured in and when it had all drained out. That amount of time is a measure of the soil's water-holding capacity.

4. pH

For you, the easiest thing to do is to use soil pH kits purchased from a biological or garden supply company. They are quite inexpensive and have easy-to-follow directions. Ideally, provide each team with a kit, but if you can't afford that, two teams can share a kit, or you can subdivide one.

Many kits provide tests for the major macrominerals (N, P, K) as well as pH. While you might wish to have several of these kits available, it is not necessary for simple pH tests.

Emphasize to your students that pH is a logarithmic scale. Each whole number differs from the next by a factor of 10 (i.e., pH 5 is 10 times more acidic than pH 6 and 100 times more acidic than pH 7).

Results

As was true in the last investigation, individual students have seen only part of the picture and need to share their findings in order to complete the picture. Comparisons among the different sites are crucial to student understanding. Comparisons can be made in one of two ways.

You can have each team in turn report its results, by putting the data sheet information on the board. Then the class can compare the different sites and draw conclusions. Or you might compile a composite table from all the data sheets, which you can duplicate and hand out prior to discussing the results. Whichever method you choose, you should preserve the results in a composite table, following the style of the data sheet. The composite will be used in subsequent investigations. Post a copy beside the map. You might want to include some of the data from this investigation on the map.

Supplies for Each Team

- tote box
- trowel
- quart jar (wide-mouthed) with cap
- liquid detergent and teaspoon
- PVC coupling or tubing, 4″ diameter
- watch
- soil pH test kit

Class Supplies

- bucket of water and dipper or hose
- map (from previous investigations)

Spinoff Idea

Suggestion for a spinoff investigation:

- Effects of Leaching and Erosion on Plant Growth

References

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Investigation 4

Soil Analysis

Student's Section

This investigation is concerned with some of the physical properties of soil that are important to organisms. Different teams will be assigned to different sites so that the variations in the soils on the school grounds can be determined and then compared.

Select one spot on your site to study the soil. All the tests are done on soil below the surface, so dig a hole several inches down. Pile the soil to one side. If you dig on the lawn, remove a clump of sod about six inches in diameter and set it aside, in the shade, with the roots down. When you've finished, replace the soil and sod in the hole and tamp it down carefully.

Record the results of each test on the data sheet as soon as you have them.

Directions for Obtaining the Data

1. Preliminary Examination

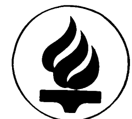
Pick up a handful of soil and examine it closely. You should be able to see the different components. Minerals are light-colored, rocky, and angular. Humus is dark and contains fragments of twigs or other recognizable bits of biological material.

a. Composition

Determine the relative amounts of minerals and humus present.

b. Friability

Friability refers to the texture of the soil, **not** whether it can be fried. It's a gardener's term. Pick up a handful of soil, squeeze it tightly, then open your fingers. If the soil is powdery (dry or sandy with low organic content), it will run through your fingers. If the soil forms a ball that crumbles when you release the pressure, it has a high organic content and is said to be "friable." If the ball holds together, it is wet or has a high clay content.



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2. Mineral Content

This test is based on the rate of settling of different minerals from a water-soil mixture.

Pour water into the quart jar until it is about half to two-thirds full. Add one to two teaspoonfuls of detergent to speed up the settling of the tiniest particles. Swirl to mix the detergent with the water, then add soil until the jar is almost full. Screw the cap on tightly and shake the jar vigorously so the contents are thoroughly mixed. Let the jar stand while you do the other tests. Then examine the layers that formed in the jar and determine which minerals are in which layers. Do that without stirring them up.

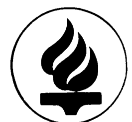
3. Water-Holding Capacity

While the lives of all soil organisms depend on the ability of the soil to hold water, that is difficult to measure. It is easier to determine drainage. The two properties, water-holding and drainage, are opposites, found in all soils but differing in rate among different soil types.

Stand the PVC tube on end and push it about two inches down into the soil. That's easy on cultivated soil and next to impossible on lawn or paths. For them, mark a circle with the tube, cut down with the trowel to form a channel, and set the tube in it. The tube should be about two inches down into the soil and firmly in place. If it isn't firmly set, pack soil around the outside of the tube, but don't disturb the soil on the inside. Fill the tube with water and record the time when the water was poured in and when it had all drained out. That amount of time is a measure of the soil's water-holding capacity.

4. pH

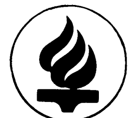
Follow the pH test kit's directions.



Name ______________________________ Date ______________

Investigation 4:
Soil Analysis

DATA SHEET
Date:
Site:
Team Members:
1. Preliminary Examination:
a. Composition: *Mostly Mineral* ———— *Equal Amounts* ———— *Mostly Humus* *b. Friability:* *Powdery* ———— *Crumbly* ———— *Holds Together* (Circle the terms that most accurately describe your soil sample's composition and friability, or put a check mark on the line where it belongs between two terms.)
2. Mineral Content: Sketch of a Jar at End of Settling Period, layers labeled:
3. Water-Holding Capacity:
Time When Water Drained OUT = *Time When Water Poured IN* = *Drainage Time* =
4. pH:



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Spinoff Idea

- **Effects of Leaching and Erosion on Plant Growth**

If you're wondering what makes soils different and how that might affect growing plants, here's your chance to find out more.

Soils with plenty of humus retain water and minerals, making them available to plants, but in soil with little humus, water flows through, carrying dissolved minerals with it to the ground below the root zone. That process, deep within the soil, is called leaching, and the visible effect on the surface is erosion.

Do some reading on the subject so that you know what eroded soil looks like. Then look around the school for areas of erosion. Read more about the process and do some experiments.

You'll need containers, seeds, and soil. Regular plant pots aren't necessary; you can use cardboard milk cartons just as well. Use the half-pint size, or cut the tops off larger ones (all the cartons should be about the same size). Punch holes in the bottom for drainage, and fill some cartons with soil from the eroded site and others with good garden soil. Use only one species, one whose seeds germinate readily (such as the bean), and plant one seed in each pot. You'll need a number of plants (5 to 10) growing under the same conditions before you can draw any conclusions. Remember that not all seeds germinate, so set up a few more pots than you think you'll need.

When you collect soil, be careful not to disfigure the landscape with your digging. You can return the soil when your investigation is over, but meanwhile smooth out the site to make the digging inconspicuous.

Treat all the plants the same way as far as light and water are concerned. Continue the experiment until the plants are well into the juvenile stage when they are on their own and no longer dependent on nutrients from the seeds or cotyledons. Compare the size and rate of growth of the plants grown in the two kinds of soil.

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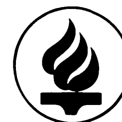

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