VOL. 1, NUMBER 2

Cambium

INNOVATIVE CURRICULUM FROM THE ARBOR SCHOOL OF ARTS & SCIENCES

In this issue

ARBOR SCHOOL
OF ARTS & SCIENCES

BACKYARD SCIENCE

Walk into any large bookstore, head for the children's science section, and be amazed at the number of books eager to pour science into the brains of the young. Shiny volumes with titles like *Cool Stuff Exploded*, *Scien-trickery*, and *Foul Facts Science* are filled with brief explanations of age-old questions: What makes the rain? Why are there slugs? What makes the car go? Why do moths eat wool? If I could dig down for five miles, what would I find? Thousands of questions are handily answered, accessorized by stunning photos or illustrations.

Children come away from these books with an appetite to see, touch, smell, to deconstruct and test the properties of the creatures, objects, and theories now buzzing in their conscious curiosity. So many of the animals, places and ideas appear exotic and out of reach. The readers do not realize that the satisfaction they seek lies in the most accessible places: in the backyard, in the cracks in the sidewalk, in the puddle, the rotting log or leaf pile, in the night sky, deep in the refrigerator, and in all their everyday surroundings lie microworlds ripe for science.

Starting With Little Things

Love the earth like a mole,
fur-near. Nearsighted,
hold close the clods,
their fine-print headlines.
Pat them with soft hands–

But spades, but pink and loving: they
break rock, nudge giants aside,
affable plow.
Fields are to touch:
each day nuzzle your way.

Tomorrow the world.

–William Stafford (1914-1993)

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In the Arbor K-8 science curriculum, the backyard is the main stage. Our Oregon campus offers acres of woods and a stream in which to observe, dig, collect, sort, compare and contrast, dissect, magnify. But any environment, natural or made, urban, ex-urban, or rural, holds rich possibilities. As you follow our students in their discoveries of the properties of seeds during germination, of the dirty little secrets of dirt, of the animals in the stars and the vastness of our universe, and of the hidden hordes of terrestrial invertebrates beneath our feet, we hope you will view your own school's environment afresh.

There is nothing fancy here: no day trips to science museums, no expensive equipment, nothing more than open eyes ready to look closely at the world in which the children move and breathe. With careful planning and enough time, teachers are able to open a whole new world to their students, starting with the first step out of the back door.

– Lauren Ferris
ICCI Consultant

GOLD AND A PINE NEEDLE

JUNIORS DELVE INTO SOIL SCIENCE

by Jane Lindquist and Janet Reynoldson

When we introduce the science of geology to the second- and third-grade Juniors, we begin with a homework assignment during the summer: collect a rock, some sand, or some soil during your travels, whether you've taken a family road trip to the beautiful red sandstone formations in the Southwest or waded up a creek to a fishing hole closer to home. The Juniors arrive in September bearing shards of obsidian; quartz crystals; smooth river stones; pockmarked volcanic deposits; bags of fine sand; fingers of gritty, striated sedimentary rock. We begin by noticing the attributes of these samples, their beauties, their differences and similarities. The students will move through assays of the soil at school (the subject of the lessons presented here) to modeling the formation of different kinds of rock, studying the history of local geological processes, and writing research reports on phenomena from the Missoula Floods to earthquakes. Throughout, building skills of observation and accurate description is paramount.

At Arbor, we do the preliminary lessons of this string with children as young as kindergarten age. We find they are quite capable of learning to use a microscope; Senior science teacher Jane Lindquist visits the lower grades to teach this skill early, both to bolster the children's scientific inquiries and to encourage their native inclination for close observation of the natural world. Inexpensive plastic magnifying glasses are adequate tools for this lesson string, but if you have access to microscopes, the soil cards your students will create make perfect subjects to practice observing under the scope.

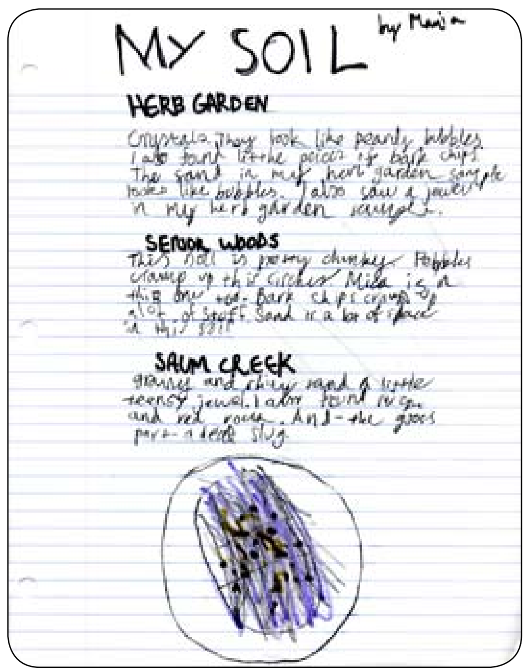
Materials:

- a tray of soil for each pair of students, or small plates for individuals
- magnifying glasses
- toothpicks
- tweezers
- microscopes

FORECAST

Day 1: What Is Soil?

Introduce the idea that the students are going to be scientists examining soil. Discuss why it might be useful to know what's in the soil—a gardener might want to know if the soil is healthy for growing plants; an engineer might want to know if the soil will be easy to dig in to lay the foundation of a building; a biologist might want to know what kinds of creatures could live in the soil. Ask what they expect to find in the soil samples you have laid out for them; record their ideas. Talk about how scientists make observations, demonstrating how they might use the tools you've assembled and—most importantly—how to write down what they see. Emphasize the power and importance of descriptive language and detail: just recording "a rock" in their notes is not very scientific. How large is the rock? What color? Is it rough or smooth? Shiny or dull? Let them begin examining the soil and making notes.



Are students recording their findings with care and accuracy? Younger children will need help thinking of appropriate adjectives; circulate and engage individuals in brainstorming as they show you what they've found.

At the end of the session, ask the children to share one item from their records. (Expect fanciful interpretations: one student wrote she'd found "gold, and a pine needle;"

another recorded "a little teensy jewel." The world under the microscope doesn't become any less magical when they later learn to identify mica and quartz.) How closely do their discoveries match their predictions? Homework: ask students to collect and bring to school in a ziploc bag samples of the items they determined could be found in soil.

Your soil ingredients will probably include dead plants, dead bugs, rocks, sticks, and water (if the soil is moist).

Day 2: How Does Soil Form?

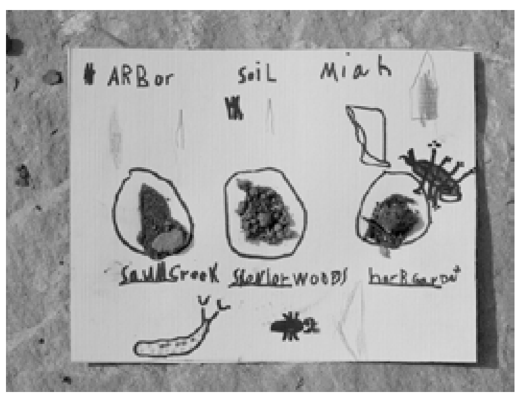
Share the bags of soil ingredients and ask whether they contain most of the things found in the soil samples. So why isn't the bag full of soil? Discuss their theories and lead them to the concept of time. How long would it take for these items to break down and become soil? Their answers will probably be wildly inaccurate; point out that making predictions is what scientists do all the time, and they're often wrong. Science is a cycle of observing, guessing, observing some more, revising your predictions, etc. Talk about the factors that affect how soil forms—what might make the ingredients in the bag break down more quickly? Ask them to predict whether all the soil on the school campus (or in a nearby park, if your school is urban) is the same. Where might it be different? In areas that are sunnier, shaded by trees, near water? Close with the promise of investigating this question in the next lesson.

Keep the bags in the classroom to observe over several weeks. If there is some moisture in the bags, you should begin to see some decomposition of the organic matter.

Days 3-4: Making Soil Cards

Materials, Days 3-4:
- teaspoons
- paper cups with lids
- magnifying glasses
- markers
- Elmer's glue
- index cards

Lead the class outside to collect soil samples from different areas. Each student should collect a teaspoon of soil at each site and add it to a paper cup labeled with the name of the site (you'll probably fill several cups at each location; hot drink lids will keep soil from spilling as the children carry the cups). At Arbor, we collected soil by the creek, in the forest, from molehills under the apple trees, and from the various gardens. Stop to use the magnifying glasses and talk about anything interesting the children notice about the soil as you go.



Back in the classroom, demonstrate how to make a soil card by drawing three 1" circles on an index card, smearing Elmer's glue in the middle of the circles, carefully spooning a little soil onto the glue, and labeling that soil's origin beneath the circle. The students should work on one sample at a time and allow each to partially dry before working on the next sample, rather than putting glue in all three circles at once and almost certainly mixing the samples by accident. Each child should put her name on her soil card so she can make observations from the same samples over several days.

Days 5-6: Microscopes

Materials, Day 5:
- As many microscopes as you can collect and reasonably expect to monitor during use
- Magnifying glasses for students who are waiting to use a microscope

If your students have not used microscopes before, emphasize that these are tools, not toys, and that they take some patience and practice to use. They are fragile and must be handled gently. Show the class how to set the specimen (a soil card) on the stage, adjust the eyepieces, and use the focus knobs.

Children who have trouble seeing through the scope may do better to cover one eye. All our students were eventually successful in this lesson, but watch for frustration and make sure it isn't vented in misuse of the microscope!

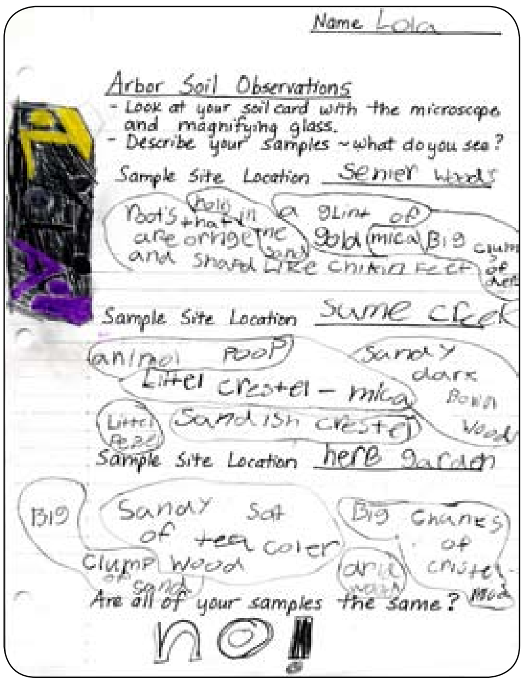
Field Notes:
Allow plenty of time for the writing aspect of the observations. If a student is struggling, ask, "What's one thing you see in this sample? Now let's see if it's in the other samples." Scaffold the mechanical process of writing if necessary; don't let a hard word intimidate a child and lead him to choose something simple and less descriptive—write it down for him if he's stuck. Writing practice is a crucial subtext of every lesson we teach at this age, but close observation and writing what you see are the most important ideas here.

Soil records and cards by Maria Gray, Jeremiah Lemelson, and Lola deGarmo.

Set the class to work with magnifying glasses, examining the soil sample cards and recording what they see in each sample. They may like to work with a partner. Remind them of the question they're trying to answer: is all the soil the same? They should be comparing the samples on their cards, noting what's the same and what's different about them. Call small groups of students up to try the microscopes. Keep the whole group engaged by periodically asking volunteers to share their best description of an object in their soil: "a small striped brown rock," "a white stringy root," "an orange root that looks like chicken feet." Why is it important for scientists to give the best descriptions they can?

Day 7: Is Our Soil All the Same?

Our students were quick to agree that their samples showed important differences. Discuss what might be causing the differences they have noted. Our samples from the creek were very sandy; we hypothesized that the water might be washing away smaller particles of soil. Our garden samples contained more organic material; we talked about how plant matter contains nutrients that help our vegetables grow. The Arbor children know that we add compost to improve the soil, and here was evidence of that compost on their soil cards. Close by asking the children to notice the steps of the scientific process they completed during their soil observations: we asked a question about what soil was made of and whether it was all the same; they made guesses about the answers; they collected samples to test their guesses; they made scientific observations of the soil and recorded what they saw; they made a conclusion that the soil samples were not all the same; and they began a new round of questions about why this might be. This is a process they'll follow again and again throughout their science education.



RESOURCES

If possible, invite soil scientists in the community to come and talk with the kids about the importance of soil. College professors, farmers, and forest service employees could all be valuable experts.

http://websoilsurvey.nrcs.usda.gov/app/ is the USDA Natural Resources Conservation Service's omnibus soil data site, covering nearly 100% of US counties. Here you can find detailed information about the content and quality of the soil in your region, should your class wish to explore further.

Carolina Biological Supply Company (www.carolina.com) has inexpensive litmus paper for testing the pH of your soil, if you are interested in collecting more scientific data.

THE BENE IS GRINSH AND DELICIT

PRIMARIES TAKE A CLOSE LOOK AT SEEDS

by Felicity Nunley

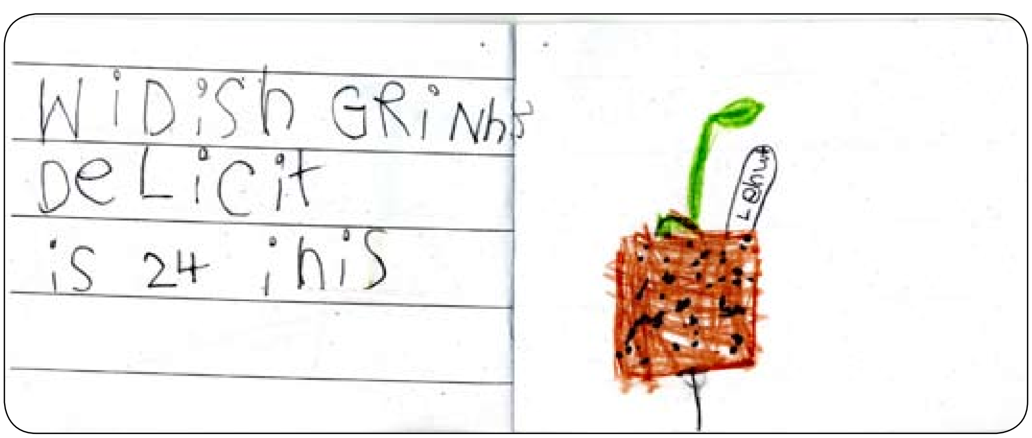
Primary children—kindergarteners and first graders—are, by their nature, devoted observers. A drowsy autumnal bee in the driveway can delay departure for 20 minutes as it drunkenly rolls itself from front to back, weaving its way on unsteady legs. A banana slug creeping across a trail deserves an enthusiastic celebration—the slime it leaves behind never fails to elicit groans of total satisfaction. The Primary children find woolly bear caterpillars and spiders. Their quick eyes catch the flash of a squirrel's tail or a blue jay lighting on a fir branch.

In the Primary classroom, we practice "looking" every day. Our classroom is full of interesting seeds, nests, rocks, knickknacks and much more for the children to pick up and feel, inspect with magnifying glasses and binoculars. A more formal "looking" exercise is one that we have nicknamed Art Look. Following the work of Philip Yenawine and his program "Visual Thinking Strategies" (www.visualthinkingstrategies.org), once a week we settle in to look closely at a piece of art. Rich discussions ensue when a teacher poses simple, yet expansive questions:"What can you find in this picture?," "What else can you find in this picture?," "What is going on in this picture?," and "What do you see that makes you say that?" The nature of the questions teaches children the habits of gathering, interpreting, and supporting conclusions with evidence.

It was our hunch that these simple questions and habits would richly inform our work in other parts of the curriculum as well. We had heard that another school had applied this technique to math exercises, and we were interested to try this question progression in science. The spirit of collaborative discourse, of being persuaded by a colleague's hypothesis, or of finding evidence to support and strengthen one's own ideas seemed central to our goals in science.

While planting a bean seed and watching it grow is hardly a new idea, our experiment was to apply our habits from Art Look to scientific observation. The class was planned to fall after an active time so that the Primaries' bodies were ready to sit long enough for careful observation and could attend to the give and take of dialogue. As in Art Look, we allowed for 15-20 minutes of observation, questioning, and discussion, followed by recording in our science journals. Rather than writing a set of instructions for these lessons, I have chosen to show the twists and turns of my class's noticing. This is only one permutation of the conversation; another class might notice entirely different things. That's the beauty of backyard science: it all begins with what a single scientist notices and wonders, and flowers through the discussions she has with her colleagues.

This year of the Primary curriculum is roughly divided so that we can study the plant cycle, the human body cycles and systems, and the cycles of critters hatching. We chose the Cycles Theme in part to give young children a framework in which to organize their spontaneous observations. Knowing about cycles helps them intuit and make predictions, or interpret behavior as part of a larger picture—a valuable skill academically and otherwise. They are quick to recognize cyclical patterns everywhere once the idea has been introduced.



Materials:
- bean seeds, preferably Scarlet Runner or another colorful variety
- peat pots or other small containers
- potting soil
- rulers
- magnifying glasses
- art supplies

FORECAST

Session 1: Bean Seeds

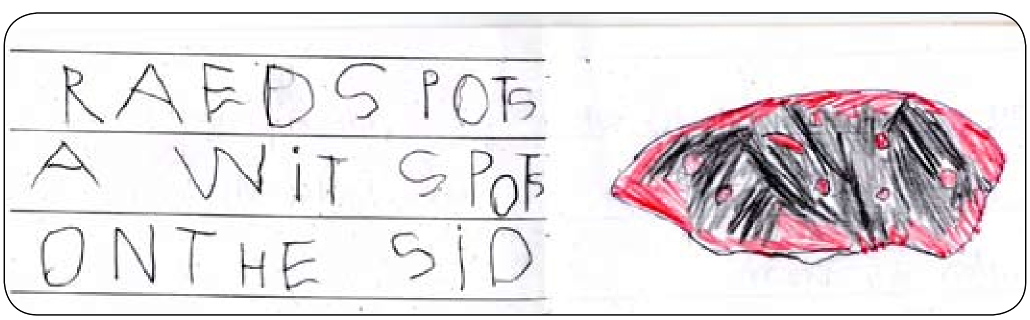
On Friday we gather as a group and I pass out a scarlet runner bean seed to each child. These beautiful spotted seeds are immediately captivating and their large size makes for easy handling. After the kids have had a moment to inspect them, I ask what they notice about the seed.

Lehua: It's hard.
Isabella: It's smooth.
Ruby: I think it's plastic.
Me: What about the seed makes you say it's plastic?
Ruby: Like Lehua said, it's hard and it's smooth. And plus, when I drop it, it sounds like plastic.
Emilio: The red and black are like they're having a war.
Me: What about the red and black makes you say they're having a war?
Emilio: Well, they're all swirled around. And there's more red over here.
Peter: My bean has brown all around the edges.
Hayden: I can see white shining through.
Jasper: I can see white, too. There's a crack in my black.
Me: Ah, I see Jasper's seed has a crack in its seed coat so we can see the embryo coming through. Does anyone else have a crack in the seed coat?
Nina: I have a little white spot in the side of my seed.
Harper: Me, too!
Cole: Me, too!

Quickly we discover that we all have a white spot on the side of our seed.

Me: Why do you suppose all the seeds have that little white spot?
Peter: That's where the root will grow.
Emilio: No, that's where the plant will grow.
Peter: That's where they both will grow 'cause the root and the plant are the same thing. One grows up and the other grows down.
Me: As we watch our seeds grow, let's remember to keep a careful watch on what happens with that white spot.

With our curiosity piqued about that curious white spot, we get out our science journals and carefully record what we see.



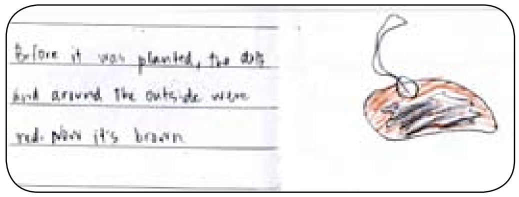
We returned to Gibbons's book to read new sections as our beans grew.

Afterwards, we read a section of Gail Gibbons's *From Seed to Plant*, paying particular attention to the diagram of seed parts. The children plant their seeds in peat pots and carefully write their names on Popsicle sticks to identify their bean plant. I plant a few extra seeds in case we need a replacement later on, and so we'll have spares we can pull up to observe in the next session without damaging the students' plants. We close by reading Arnold Lobel's *Frog and Toad* story, "The Garden."

I love being able to capture my students' comments on sticky notes as a record of each child's developing observational skills and remarkable insights. This can be hard to do while leading the discussion; it's most easily managed if you can enlist the help of another teacher or a parent volunteer who knows the class well to take the notes. Otherwise, a tape recorder might be useful during these lessons.

Arbor issues narrative reports rather than grades; anecdotal evidence captured on sticky notes can be invaluable during report writing week.

Session 2: Roots

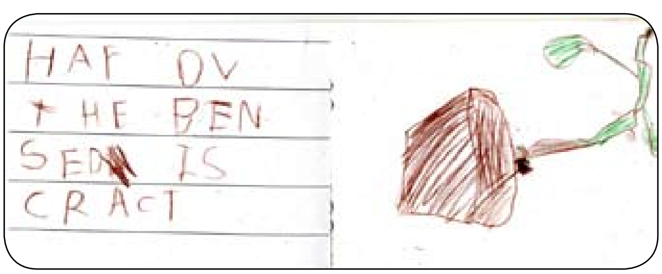


On Monday morning, we are eager to check out our bean plants. There's nothing to see above the soil line yet, but I dig up a few of the extra seeds to see the growth of the root. This time we do not meet as a large group, but in small groups of four or five so that we can easily see the examples. This changes the dynamic of the discussion a bit, and this time we have our science journals out as we look. We have magnifying glasses in hand, and again I ask, "What do you notice about the bean seed?"

Lehua: The seed coat changed color—it's lighter now and squishy.
Jasper: The seed coat is totally torn open.
Peter: The root is growing down.
Hayden: That's not the root. That's the sprout.
Me: What do you see that makes you say that it's the sprout?
Hayden: It just is.
Peter: I know that that is the root, because it's white and besides, it's too thick to be the sprout. The sprout is going to be skinny.
Me: So you've seen a sprout before and it was skinny and that makes you say that is the root?
Peter: Yeah.
Hayden: Which side was down?
Me: Um. I didn't really pay attention as I pulled it out of the pot.
Sarah: I'll pull mine out! (*Sarah pulls hers out without fanfare and holds it up for us to see.*) This, this was down so it's gotta be the root.

Sessions 3-5: Shoots, Leaves, and Further Growth

Over the next several days, the students rush to check their bean plants every morning. It is with great pride that each announces the first sprout of his bean plant. Every few days, we convene to talk about what we notice. We notice that, as the plant grows taller, the leaves grow opposite each other on the stem of the plant. We notice the heart shape of the young leaves and their vein pattern. We look in bemusement as one plant continues to "wear" its seed coat even as it grows tall. We are astounded that in one day, our tallest bean grew two inches. We predict that at that rate of growth, it will be 14 inches by Friday. We measure throughout the week and notice that its growth has slowed; on Friday we are a little disappointed, but still proud of our 11-inch bean.



Evident throughout this unit was the devotion of the kids to their bean plants—they checked them daily; were proud of their growth; cheered on the plants that were late; worried when their growth was not up to prediction. They had become stewards as well as careful observers. And the simple Art Look questions had helped them become seekers of scientific evidence.

Bean journals by Lehua Waianuhea and Cole Powers.

SEVEN THOUSAND SPECIES
SENIORS DISCOVER TERRESTRIAL INVERTEBRATES

by Jane Lindquist

Arbor's campus—twenty acres of Oregon woods, fields, gardens, and a stream—is home to more than 7,000 species of invertebrates, according to Oregon State University insect ecologist Andy Moldenke, who visited the Senior sixth, seventh and eighth graders this fall. Our species range from woolly bear caterpillars, tenderly rescued from the driveway and paths by the youngest students, to the ubiquitous banana slugs and the crayfish in the creek, to the myriad springtails and other microscopic creatures that blanket the forest floor and the bark of the trees.

Every third year, Arbor Seniors spend most of the fall studying terrestrial and aquatic invertebrates, building capture devices and learning how to use them to collect and identify specimens, designing and conducting independent experiments, and even celebrating with a potluck lunch of everything from shrimp and crab dishes to fried crickets. (Vegetarians nod to the theme with pasta shells and the like.) The lengthy unit requires our students to steep themselves in the practices of serious scientific observation and recording. The simple tools they construct and use are those used by working entomologists; their assignment to capture, identify, and illustrate more than thirty different species is a real challenge. The possibility of discovering a nondescript invertebrate is very real, as is the possibility of a well-designed student experiment advancing scientific knowledge of this vast group of animals.

Best of all, invertebrates are everywhere. Even if your school doesn't have a backyard like Arbor's, you'll find them in the foliage and soil of the landscaping, on street trees, on the playground. Invite your students to look more closely.

Invertebrates are most abundant in warm weather. Try to plan this unit for early fall or spring, when the students will be able to observe a wide variety of species.

FORECAST

Week 1: Build and Learn to Use Capture Devices

To collect a variety of invertebrates, you'll need to construct or purchase three simple devices.

Pitfall Traps: A pitfall trap can be made from a small garden plant container or a plastic cup and a plastic or metal cone that fits inside the container. The trap is set in a hole, the rim flush with the level of the ground, so that bugs traveling on the surface will slip down the cone into the cup. We build some of our pitfall traps with a layer of plaster at the bottom that can be moistened to make the atmosphere more comfortable for the trapped insects. Metal inserts are easily made by bending a foil rectangle into a cone of the proper diameter, then cutting the excess material from the top.

A pitfall trap can easily be converted into a Berlese funnel to capture arthropods that live in the soil, or you can use a standard plastic kitchen funnel if the aperture of your pitfall insert is too wide. To set up a Berlese funnel, place a scoop of the top 5-6" of undisturbed soil in the funnel, set the funnel over a cup or jar, and place the apparatus directly under a desk lamp. The arthropods will flee the light and heat, traveling down through the soil until they drop through the funnel opening into the jar.

Beater Sheets: Cross a pair of meter sticks and cut a square of canvas of the correct dimensions to accommodate the sticks (crossed upper-left corner to lower-right

and lower-left corner to upper-right), plus a seam allowance. Cut four right triangles of canvas for corner pockets to hold the meter sticks in place. Sew a triangle into each corner, turn the resulting pockets inside out, and stitch down the unfinished edges of the square toward the back of the beater sheet. (You may wish to enlist a parent volunteer if you don't have a sewing machine at school.) Gently shake bushes, branches, or grasses over your beater sheet to dislodge invertebrates, then use an insect aspirator to suck them off the sheet and into a small glass container for transfer to the lab.

Sweep Nets: Butterfly nets are inexpensive and widely available, and are the best way to capture flying insects.

Spend some time outdoors practicing gentle use of your capture devices; the goal is to take the invertebrates alive and return them to their point of capture unharmed after you've observed and identified them. You'll want to set up a number of small holding containers (with sources of food; samples of the plants you found them on or a cupful of dirt for soil dwellers will do) to keep them in the classroom for a few days while you study them. Plastic petri dishes with covers work well for storage of specimens. You can place these directly under the dissecting microscope to observe the live invertebrates within.

Independent Projects

Students are asked to think of a research question and hypothesis based on their work with invertebrates. We require each student to pursue a unique question; you might opt to let yours work in pairs. Each must design an experiment to test her hypothesis, perform the collection and identification, analyze the results, and write a conclusion.
Arbor Seniors' recent research questions included:

– *Does a 20-degree difference in temperature affect the types of species and number of species found on sword ferns?*
– *Using a Berlese funnel, will I be more likely to find pseudoscorpions in a disturbed or undisturbed area?*
– *Does placing a light bulb above a pitfall trap affect the variety and number of invertebrates caught in a pitfall trap?*

You'll want to guide students' topic choices according to the time frame for your unit. Long-running studies tend to yield the best data, so consider making your science periods flexible enough to permit some students to continue monitoring an experiment for a number of weeks. Help your students be creative in designing projects that will let them follow a question that interests them, but will work within the limitations of your schedule.

Look for detail in descriptions and make sure the components of the research paper are thorough and logical. Check in with individuals as they work.

Field Notes:
Don't set pitfall traps before a rain, or you'll drown your catch.

Encourage your students to work quickly during the observation and identification process so that you don't have to keep specimens for more than a couple of days. Some of our students are upset when the animals die in captivity; while the animals they are trapping are incredibly numerous and our science is not threatening their species' survival, it is important to be sensitive and careful in handling the catch.

RESOURCES

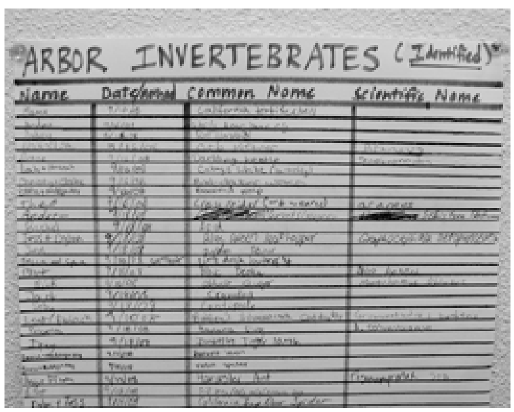
The best resource of all is an actual scientist. It's worth contacting the ecology or microbiology department of a nearby university to see if anyone who studies insects or other invertebrates might be willing to make a classroom visit to talk about the profession and help your students identify bugs they haven't been able to find in the field guides.

Identification is the most difficult part of any invertebrate study. Gathering the right field guides is critical. Nationwide, these are good:

Borror, Donald J. and Richard E. White. *A Field Guide to Insects* (Peterson Field Guide Series). New York: Houghton Mifflin, 1998.

National Audubon Society. *Field Guide to North American Insects and Spiders*. New York: Knopf, 1980.

You'll need other guides for your specific region, too. Your state's Department of Environmental Quality and Department of Natural Resources may be good places to seek recommendations.



Pacific Northwest books:

Hafele, Rick and Steve Hinton. *Guide to Pacific Northwest Aquatic Invertebrates*. Oregon Trout, Portland, OR

Haggard, Peter and Judy. *Insects of the Pacific Northwest*. Portland, OR: Timber Press, 2006.

Acorn, John and Ian Sheldon. *Bugs of Washington and Oregon*. Lone Pine Publishing, 2001.

Wolftree Ecology Field Guide: Watershed Science Programs. Portland, OR.

Online:

If you have the habitat to study aquatic invertebrates, nwnature.net has a good bibliography of print resources and Internet links for their study and identification: http://www.nwnature.net/macros/resources.html

There are some terrestrial guides here, too. These are mostly geared to the Northwest, but the links include resources for New York, North Dakota, and Maryland, among others.

Insect aspirators for use with beater sheets are available from Carolina Biological Supply Company (www.carolina.com) for $10.95. They also sell pitfall traps and sweep nets (search for "butterfly net") if you choose not to make your own.

Senior researchers pictured: Zack Swafford, Bryan Semonsen, Alan Hermanns, Lilah Buchanan, Aggie Fitch, Sophie Schoenfeld, Alex Lam, and Ian Brok.

HEAVENLY MOTIONS
INTERMEDIATES OBSERVE THE MOON AND STARS

by Charles Brod

Stars, planets, moon and sun bring a wheeling kaleidoscope of transformation to the sky. While in this technological age it is easy to ignore the cycles of the sky, for centuries celestial motions marked the steady advance of time and seasons. People woke and rested, planted and harvested, migrated and navigated by sky markers. Every second year at Arbor, fourth- and fifth-grade Intermediates embark on a study of ancient civilizations, the Middle Ages and the Renaissance. A major thread throughout is the development of humankind's understanding of our place in the universe. We attempt, as does Brian Greene, author of *The Elegant Universe* and *The Fabric of the Cosmos*, to use science discoveries to "fire the imagination and instill a sense of connection to our lives and our world." Over the years, the astronomy curriculum has evolved to better capture the big ideas that inspire students while also developing the observational and research skills that support budding scientists and astronomers.

This year we launched into astronomy early with summer homework that asked children to observe the waning moon in the daylight morning hours, measuring its distance from the sun by counting fists at arm's length. With the clear skies of summer, children were able to observe over several days the apparent increasing proximity of the moon to the sun. They also noted the moon's change in appearance from waning gibbous to last quarter to final crescent shape before it receded into the sun's glare as a new moon. Armed with this data once school convened in September, students made further observations in the early evenings as the moon waxed toward a full and spectacular harvest moon.

Our astronomy unit lasts several months; collected here are some of the astronomy lesson strings that we have found most resonant with our students.

FORECAST
Week 1: Moon Modeling

Materials:
- *a standing lamp with a bare bulb*
- *small styrofoam balls*
- *pencils*

Despite having observed and recorded the moon regularly, many students still cannot solve the puzzle of the moon's shifting phases. Many hold to the misconception that it is the earth's shadow falling on the face of the moon that changes its appearance. Others incorrectly believe that the moon circles the earth once each day instead of over a 29.53-day cycle. To test these ideas, we physically model the motions of the earth and moon in relation to the sun. With some questioning, students can recount their morning and evening observations. Using a darkened space, a light bulb for the sun, a pencil and a styrofoam ball for the moon, and students' own heads for the earth, we begin to sort out the complex sequence of motions involved.

Modeling a waxing crescent moon

Working from students' own observations and knowledge of the daily "rise" of the sun in the East and a mental image of the United States, I ask them to imagine the U.S. spread across their faces and to place a hand on their "East Coast" cheek. With this geography underscored, it is relatively simple for them to circumnavigate the light bulb "sun," spinning in the direction (leftward) that creates the apparent

Field Notes
This request often causes initial confusion; students look at each other and even at a globe before putting a hand to the left cheek. Let them struggle with it and debate with a partner if necessary.

I've often been surprised to see how many students place the moon between earth and sun when asked to position it for a full moon. By checking each other and reviewing their logic, the class eventually finds the proper alignment of sun, earth and moon, but be prepared to ask leading questions about what you can see in the sky when your part of Earth is facing the sun.

Behind the Scenes, Solar System Walk:
Read Guy Ottewell's lesson plan (see **Resources**) and gather materials to represent the planets according to his directions.

Ottewell wrote his lesson in 1989, before Pluto's demotion to "dwarf planet." You may wish to omit it, saving yourself the last 242 paces.

sunrise in the East and setting in the West. Once we have established this elusive idea (remember it took centuries for humans to fully accept a heliocentric view of the solar system), we can move on to mounting styrofoam balls on pencils to model the moon's movements. Establishing the sun, moon and earth alignment for a new moon is a natural next step. From there the students proceed to find the waxing crescent by rotating slightly to the left, then on to first quarter, gibbous and full moons, all the time reflecting back to what they have seen in their evening observations. This modeling quickly clarifies students' thinking about the monthly cycle of lunar phases and also opens up discussion about solar and lunar eclipses, the moon's "earth lock" rotation that never lets us see its far side, and human space travel.

A few days later, ask the students to draw the positions of sun, moon and earth during the different phases: it takes time to cement these complicated ideas. The modeling activity gives kids something kinetic to remember as an aid.

Solar System Walk

(two days, plus a third if you want your students to work out the scale of the walk themselves)

Physical modeling of heavenly bodies not only helps children to understand their motions, but also can underscore the vastness of space. A favorite and awe-inspiring activity for students is to go on a thousand-yard walk that encompasses the solar system. Guy Ottewell's model (see link in Resources), unlike many others, establishes a common scale for the size of planets and the distances between them. Using one inch equal to 100,000 miles, a single pace of a yard becomes a journey of 3,600,000 miles. The earth is reduced to a peppercorn and the sun is no larger than an eight-inch diameter soccer ball. In an hour's time it is possible to briefly touch on the math using a yardstick to build up distances from an inch to a full pace, and then head outside with materials for sun and planets. While students could spend considerable time working through the math involved in this activity, we choose not to get bogged down in numbers so that the more striking ideas come to the fore. Students are truly amazed when we march off to place the planets—scaled to seeds and nuts, with oceans of grass separating them—ultimately walking nearly half a mile before setting Neptune down.

As a follow-up, ask students to generate a reflective piece. It can be a straightforward account of the walk or a more elaborate mapping of the solar system against the terrain of the school with the various seeds and nuts designated along the way. The reflections never fail to reveal that students are truly awestruck by the expanse of space and man's puny efforts to travel some small distance in its realm. Arbor graduates remember this lesson almost twenty years later.

Weeks Two, Three, and Four: The Constellation Guide

Our culminating activity is the creation of a constellation guide. Each student creates a small book about a constellation of her choice. This book contains research and beautiful drawings of star groupings and the figures of myth that encompass them. The project enfolds elements of Greek mythology and other ancient civilizations studied simultaneously in the thematic curriculum as students retell the myths behind the constellations. They hone basic research skills as they gather the constellation's Greek or Latin name, the stars that form it, their apparent magnitudes, distance from earth, when and where one should look in the night sky to find the constellation, neighboring constellations, and interesting facts about the celestial objects it contains.

Days 1-2: The Zodiac

An opening lesson begins by discussing the importance to ancient peoples of observing stars and constellations to mark the seasons of the year and their progress across the face of the earth. Many students of this age are already familiar with structures like Stonehenge, Mayan temples, and Sumerian ziggurats that served some astronomical function. Early farmers and hunters set their activities based on the appearance and disappearance of constellations. Polaris and other stars were important in sea navigation until the technological innovations of the last century; early Polynesians coursed the immense Pacific with just the stars for a guide.

To understand the earth's annual progress around the sun and the changing panorama of constellations, we move again to physical modeling. A 30' strip of butcher paper with an ecliptic line running along the center and the zodiacal constellations laid out along it is a helpful tool. The zodiac ring we've used for years is based on H. A. Rey's book *The Stars*. To create your own, assign pairs of students to draw and label the twelve zodiacal constellations in order along a roll of butcher paper. Set a suitable object at the height of a stool to represent the sun, then ask students to encircle the "sun" and hold up the butcher paper with its zodiac band facing inward.

Discuss the ecliptic as the imaginary plane on which sun, planets, and zodiacal constellations are situated and how the 23.5-degree tilt of the earth charts the apparent course of these bodies at a slant across the sky. One at a time, students enter the ring, begin an easterly (leftward) spin to approximate the rotation of the earth, and then step around the circle counterclockwise, noting the rising and setting of each constellation over the months.

Be sure to discuss when those constellations are visible: if the "earth" student is facing the sun, it is daytime and he cannot see the constellations on the far side of the ring. Be sure he knows he can only view the stars visible during the half of his spin in which he faces away from the sun; ask him to call out the names of the constellations he can read once the sun is out of sight.

The zodiac is the region 9 degrees above and below the line of the ecliptic, which is the apparent path the sun traces through the sky. It is divided into 12 regions of 30 degrees each, named according to the constellations that straddle the ecliptic. "Zodiac" is thought to come from a Greek word meaning "circle of animals."

Day 3: The Planisphere

Once students have a sense of the earth's motion in relation to constellations, they can learn to use a planisphere, a simple and inexpensive device for charting the sky. Using Taurus as an example, ask students place the constellation on the eastern horizon as if it is just rising, then look to the edge of the planisphere to determine the month and day the Bull can first be seen in the evening. You'll need to point out that for a correct reading they must hold the planisphere overhead so that the cardinal directions are in proper alignment. Once they have done this correctly, they move Taurus across the sky to zenith position and then to the western horizon, noting at each position the month and time.

This serves as practice for tracking their research constellations' annual progress in the sky; we require this information as part of the constellation guide. Students with circumpolar constellations like Ursa Major and Draco have a different task: in the northern hemisphere, these constellations never set. Instead, ask them to find their constellation's quarterly progress by compass point around Polaris, the North Star. At what date and time is it directly north, south, east or west of Polaris?

I like to give homework during a week when the forecast is for clear skies. With a checklist in hand, students hunt for constellations and eagerly share those they have identified.

Field Notes:
If children aren't getting a reasonable month as an answer, ask them to check whether they're reading an a.m. time or a p.m. time.

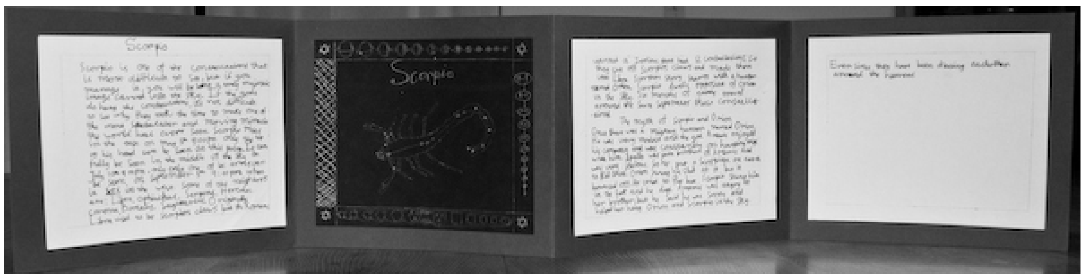
Planispheres are keyed to a particular latitude. Make sure you buy a set that closely approximates your actual latitude.

Days 4-12: Constellation Books

Students spend four to eight class sessions gathering information; arranging their notes in sentences and paragraphs; revising to add engaging introductions and clarifications, improve voice and word choice, and edit for spelling and conventions; and then producing a final beautiful copy of the work in joined italic handwriting on bordered pages showing designs drawn from astronomy. Drawings are carefully planned on graph paper and then transferred to a final page. Students take immense pride in producing a final book that displays their skill in writing, research, design, science, handwriting, and storytelling.

Once this work has been accomplished, we like to take the opportunity to celebrate. We have sometimes held star parties in the evening on campus. Students always enjoy bringing music into the mix with a performance of Eric Idle's "Galaxy Song" at a gathering for parents and other classes.

Fall weather being unpredictable in Oregon, we have also gone to a regional planetarium where "clear skies" are assured under the dome.



RESOURCES:

Guy Ottewell's lesson is online at http://www.noao.edu/education/peppercorn/pcmain.html

Hear Eric Idle sing the Galaxy Song: http://www.youtube.com/watch?v=44DlSj6bnn4
Lyrics available here: http://www.gecdsb.on.ca/d&g/astro/music/Galaxy_Song.html

Other Internet resources:

http://www.moonconnection.com/ offers a good explanation of the moon phases, real-time representations of the current moon, moon phase calendars for the next six months, and other interesting articles.
Google Moon (http://www.google.com/moon) maps the landing sites of the Apollo missions and gives data, including photos taken at each area explored.
Google Sky (http://www.google.com/sky) shows the whole sky and can be filtered for historical, infrared, and microwave views. Searchable for images of individual stars, constellations, Hubble images, Messier objects visible with a telescope, etc.

Books we like to have in the classroom include:

- Heath, Robin. *Sun, Moon, & Earth*. Wales: Wooden Books, 1999/ New York: Walker & Co., 2001.
  A little book packed with mathematical information about the motions of these bodies, beautifully illustrated by the author. Best for students who are advanced readers and thinkers.
- Levy, David H. *Skywatching* (The Nature Company Guides). Sydney and San Francisco: Weldon Owen Inc., 1994.
  Similar in structure to the Dorling-Kindersley Eyewitness nonfiction series. Children who can use an index may find it this valuable for research. Contains historical information, overviews of stars and galaxies, tools and techniques, an extensive sky guide, and more.
- Long, Kim. *The Moon Book*. Boulder, CO: Johnson Books, 1988, 1998 rev.
  Clearly written and illustrated with effective diagrams and maps; covers all things to do with the moon. Accessible to good readers, but probably most useful for lecture prep.
- Lurie, Alison, illus. Monika Beisner. *The Heavenly Zoo: Legends and Tales of the Stars*. New York: Farrar, Straus, and Giroux, 1979.

Stories of the animal constellations from all over the world, retold for middle-grade readers.

– Mitton, Jacqueline, illus. Christina Balit. *Once Upon a Starry Night: A Book of Constellations*. Washington, DC: National Geographic Society, 2003.
A picture book with brief tellings of some Greek constellation myths. More scientific information is included in an appendix.

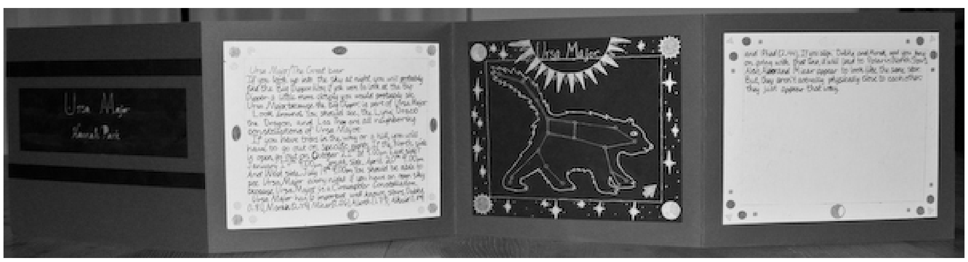
– --. *Zodiac: Celestial Circle of the Sun*. London: Frances Lincoln Children's Books, 2004.
This picture book by the same team has more text, and covers the constellations of the zodiac. The two books are complementary, as there is little overlap in the constellations covered.

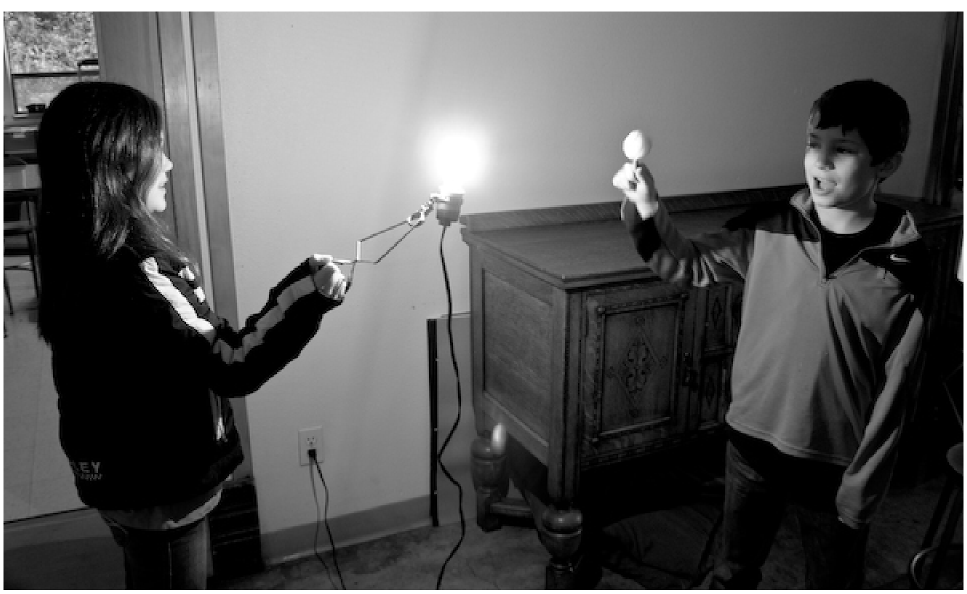
– Pearce, Q. L., illus. Mary Ann Fraser. *The Stargazers' Guide to the Galaxy*. New York: Tom Doherty Associates, Inc., 1991.
Clear, concise skywatching guide with constellation legends, written for ages 8 and up.

– Rey, H.A. *The Stars: A New Way to See Them*. Boston: Houghton Mifflin, 1952.
A classic and very useful guide to the constellations. Rey's redrawings of the mythical creatures make the groupings easier to see and remember.

– --. *Find the Constellations*. Boston: Houghton Mifflin, 1954.
Less essential than Rey's The Stars, *but an engaging guide that may help students identify the constellations.*

– Tennant, Catherine. *The Box of Stars: A Practical Guide to the Night Sky and to Its Myths and Legends*. Boston: Bulfinch Press (Little, Brown).
A collection of 32 illustrated cards with holes punched for the major stars. Hold the cards up to a light to see the star groups.





Sun and moon modeling by Maya P. and Reed Huston. Planispheres demonstrated by Anna Hall, Isabella Waldron, and Hillary Ellman. Constellation guides by Alice Fischer, Guthrie Stafford, Noah Monahan, and Hannah Park.

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Masthead by Jake Grant, after an 1890 botanical illustration. Plant block print by Annika Lovestrand.

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Bean illustration by Lehua Waianuhea

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