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ABSTRACT

This publication presents examples of inquiry-based science teaching in which students develop an understanding of the natural world. Sections include: (1) "Connecting Students to Science and the World" (Jennifer Stepanek); (2) "Apple Orchard Lush with Life's Lessons" (Helen Silvis); (3) "Student Scientists Team Up with the Pros" (Amy Sutton); (4) "Schoolyard Science Takes Root" (Suzie Boss); (5) "Classroom Resources" (Amy Sutton); and (6) "A Word from the Director" (Kit Peixotto). (YDS)

NW northwest

TEACHER

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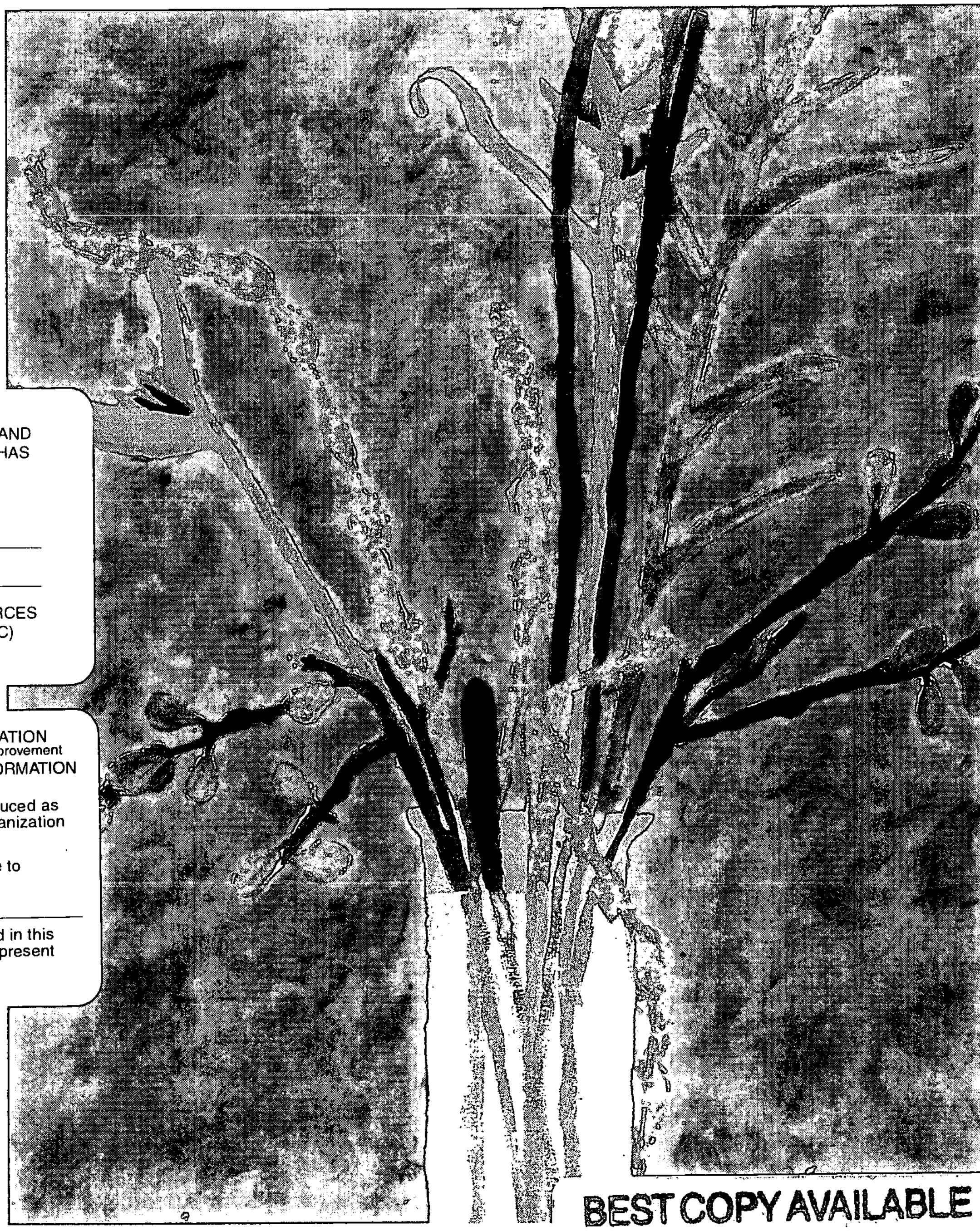
A MATH AND SCIENCE JOURNAL DEVOTED TO RIGOROUS AND IMAGINATIVE LEARNING



TAKING IT OUTSIDE:

2

SCIENCE INQUIRY

■ Connecting to Science and the World ■ Investigating Life's Lessons Among Apple Blossoms ■ Student Scientists Team Up With the Pros ■ Schoolyard Science Takes Root

Northwest Regional Educational Laboratory

NORTHWEST

TEACHER

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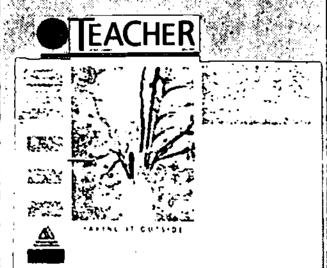

ON THE COVER:
This brilliantly colored painting of figs and birds of paradise was painted by Adriane Cloepfil, 10, a student at Portland's Innerscape Art Center.

INSIDE:
The apple blossom drawings are courtesy of Larry Alexander's fifth-grade class at Tonasket Elementary in Washington.

contents

TAKING IT OUTSIDE: SCIENCE INQUIRY

NORTHWEST TEACHER is published three times a year by the Northwest Eisenhower Regional Consortium for Mathematics and Science at the Northwest Regional Educational Laboratory's Mathematics and Science Education Center, 101 SW Main Street, Suite 500, Portland, Oregon 97204, (503) 275-9500. Single copies of the publication are available free of charge per request to educators within the Consortium's region of Alaska, Idaho, Montana, Oregon, and Washington (while supplies last). To request a free copy, contact the Consortium by e-mail at math_and_science@nwrel.org, by telephone at (503) 275-0457, or place an order from the Web site at www.nwrel.org/msec/. An online version of the publication is also available for downloading from this Web site. Multiple copies, and copies to individuals outside the Consortium's region, may be purchased through NWREL's Document Reproduction Service at the above address, or direct orders by e-mail to products@nwrel.org; by fax, (503) 275-0458, or by telephone, (503) 275-9519.

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THROWING OPEN THE DOORS to learning, teachers and pupils take to the hills, streams, and garden beds where scientific marvels await beyond the schoolhouse.

EDITORS' NOTE

DENISE JARRETT WEEKS
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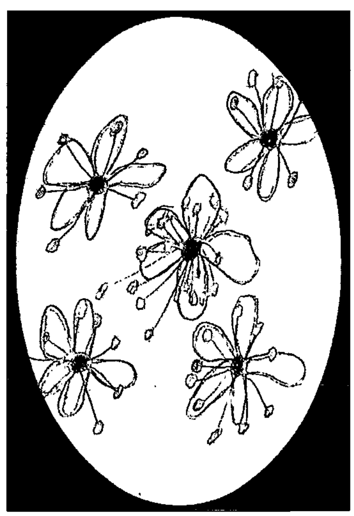
Passion is indivisible from reason, says writer and biologist E.O. Wilson in *Consilience* (1998): "Emotion is not just a perturbation of reason but a vital part of it," providing stimulus and guidance to rational thought. While brain scientists have only recently validated this view of the human mind, it's no revelation to teachers.

It's abundantly clear, especially when students leave their classrooms to learn in the "turbulence of the real world." Here, their emotions and intellect are stirred, creating the alchemy that is the wellspring of human nature. Alive with personal meaning, school grounds and the local landscape evoke emotional connections for young people. As complex systems, these environments also prompt students to think deeply and forge new ideas about how the world works. The more novel and complicated these connections, says Wilson, the more enduring is the learning.

In the stories you'll read here, teachers and students have taken to the outdoors, leaving their classrooms to unearth the mysteries awaiting in school gardens, orchards, forests, and wetlands. Equipped with the skills of scientific inquiry, students construct an understanding of the natural and built world.

Inquiry is a core principle of the *National Science Education Standards* (1996). The standards state that all students should undertake scientific inquiry, developing the ability to ask questions, plan and conduct investigations, use tools and techniques to gather data, think critically and logically about complex relationships, construct and analyze alternative explanations, communicate scientific arguments, and pose questions anew. In fact, tomorrow's leaders, Wilson predicts, will not be those who simply possess information, but those who can synthesize it—people who can "put together the right information at the right time, think critically about it, and make important choices wisely." An inquiry approach befits not only the sciences, but a lifetime that can be informed rather than impeded by a complex world.



And so it is, powered by our intellect and guided by our emotions, we seek to explore and understand our universe. In his book, *Unweaving the Rainbow* (1998), Richard Dawkins recalls the writings of some of his colleagues who observe, "Only humans find their way by a light that illuminates more than the patch of ground they stand on." Dawkins adds: "The spotlight passes but, exhilaratingly, before doing so it gives us time to comprehend something of this place in which we fleetingly find ourselves and the reason that we do so."

Our vision is that *Northwest Teacher* will serve as a tool for professional development by actively engaging readers and by speaking to them as imaginative problem solvers, thoughtful inquirers, and lifelong learners. The stories that follow were selected to inspire teachers to reflect on and talk about their own experiences and beliefs.

Professional development providers might use an article to illustrate a concept, providing time for reading and discussion. Teachers might want to share the journal with their colleagues, discussing their responses to the stories, perhaps even collaborating to try a new approach. Administrators might distribute copies to staff members, inviting them to share their reactions and reflections at a meeting or by e-mail exchanges. *Northwest Teacher* can serve as a starting point for group dialogue about issues in mathematics and science teaching, as well as for independent reading and personal reflection.

CONNECTING STUDENTS TO SCIENCE AND THE WORLD

STORY BY Jennifer Stepanek ILLUSTRATIONS BY students of Tonasket Elementary School

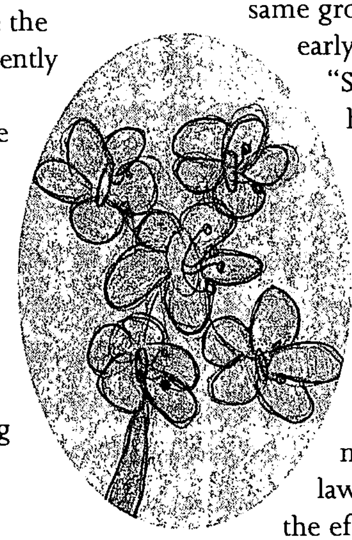
Teaching science through inquiry isn't a cinch. But its power to draw students deep into the realm of science is irresistible to many teachers who find the challenge worthwhile—and perhaps essential.

Inquiry holds a central position in the *National Science Education Standards* (National Research Council, 1996), the *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), and in the priorities of many science educators for several reasons. Inquiry teaching is more consistent with our growing awareness of cognitive processes and how students learn. Students are more likely to retain the knowledge that they gain when they build understanding through hands-on investigations that require them to make meaningful decisions. Students also develop the ability to use scientific reasoning and master the skills of doing science, such as planning an experiment, making observations, and interpreting data.

These outcomes are the ones used most frequently as the rationale for inquiry-based science teaching. Yet, there are additional and equally compelling reasons. A science curriculum alive with opportunities for inquiry draws students into learning science in a variety of ways.

the nature of science

When students engage in inquiry they gain an understanding of the true nature of science. Too often, science is misrepresented to students as a remote and static body of facts and truths rather than a process for developing knowledge and an activity in which all people can engage (Bybee, 2000). This problem has been a persistent one in science education. John Dewey criticized school science on these same grounds during the early 20th century: "Science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject matter of fact and law, rather than as the effective methods of inquiry into any subject matter" (Dewey, 1910).



Inquiry reveals science knowledge as growing and changing rather than fixed, helping to bring the field to life for young learners. Students come to understand that the ideas they are learning about are open to questioning and testing. Inquiry-based learning also recreates the sometimes messy and unpredictable methods that scientists use when they choose from a range of processes and tools (Hodson, 1998). Real scientists do not follow only one series of steps in their investigations, and their work involves discovering new questions and interpreting the meaning of results and observations.

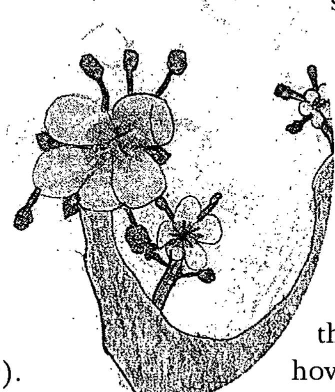
The messy and unpredictable side of doing science is an im-

> IN THE CLASSROOM, A QUESTION ROBUST AND FRUITFUL ENOUGH TO DRIVE AN INQUIRY GENERATES A 'NEED TO KNOW' IN STUDENTS.
> — NATIONAL RESEARCH COUNCIL (2000)

portant element of inquiry, but not all investigations will have the same level of open-ended learning. Inquiry often occurs on a continuum, encompassing a progression from activities that are highly structured by the teacher to opportunities for students to pursue their own questions and design experiments. While it is desirable that inquiry-based teaching reach the farthest end of the spectrum at least some of the time, the appropriate amount of structure and direction provided by the teacher will vary according to a number of factors, including the content to be learned, the abilities and interests of the students, and the instructional goals.

the power of curiosity

One of the most powerful aspects of inquiry-based teaching is its ability to excite students' natural curiosity. In his book *Nurturing Inquiry* (1999), science teacher Charles Pearce writes, "The world around them is a mystery to be unraveled and solved. Place any child in any place and he or she will begin to explore. Ideas will develop, questions will flow, discoveries will be made" (Pearce, 1999).



Too often, the desire to learn is left out of conversations about increasing student achievement. Teachers' ability to tap into and fuel students' desire to learn is a key ingredient in successful science education and meaningful learning.

This issue concerns Jolene Hinrichsen, a science teacher at Mountain View Middle School in Newberg, Oregon, who designed an instructional model for teaching science inquiry (see www.nwrel.org/msec/science_inq/).

THE LASTING PLEASURES OF CONTACT WITH THE NATURAL WORLD ARE NOT RESERVED FOR SCIENTISTS BUT ARE AVAILABLE TO ANYONE WHO WILL PLACE HIMSELF UNDER THE INFLUENCE OF EARTH, SEA, AND SKY AND THEIR AMAZING LIFE.

— **RACHEL CARSON** (1956)

"It bothers me a great deal to see apathy toward science in a young person," she says. "When I can get to the bottom of this indifference, I generally find that he has received and believed a message that he can't do or understand science the way his schools have told him he must. The kids who have been 'turned off' often have just as much need and desire to know such things as how their bodies work or how crystals form as the engaged student, but something has gone awry in how these kids explore and find out about science."

The engaged student who cares about the content and ideas he or she is learning makes an emotional investment that brings energy and excitement to the pursuit of knowledge. Students are eager to be involved in inquiry tasks that help them to solve problems from their own experiences or to answer their own questions. Personal involvement and learning are enhanced with opportunities to figure things out, to interpret the results of investigations, to generate hypotheses, and to create knowledge and meaning (Roth & Roychoudhury, 1994).

Hinrichsen also sees an inquiry-based science curriculum as a means of addressing and counteracting students' apathy. "I personally believe that kids must understand and in many cases memorize some facts of science. But most principles of science can be understood without a fact-heavy curriculum. Kids need to talk and talk and talk about daily science. They need to actively wonder about how their world works and to apply those ideas of science to their personal experience of science. They need opportunities to pursue inquiries into the scientific questions they want answers to."

SEE SCOPE, PAGE 9

INQUIRY LEADS STUDENTS DEEP INTO THEIR BURGEONING APPLE ORCHARD TO LEARN THE SCIENCE OF LIFE. ALONG THE WAY, THEY PICK UP SOME JUICY TIPS ABOUT DOING BUSINESS IN THE APPLE INDUSTRY.

Apple Orchard Lush With Life's Lessons

STORY AND PHOTOS BY Helen Silvis

TONASKET, WASHINGTON—Like Olympic runners responding to the starter's gun, the students in Larry Alexander's fifth-grade class are off and running the moment he announces that it's time to head to the orchard. Fifteen eager young bodies scramble up the dusty hillside next to the playground of Tonasket Elementary School. Racing through the aromatic sagebrush they gather at the gate, talking animatedly as they wait for their teacher to catch up.

"They are really full of energy and enthusiasm, which helps me a lot," says Alexander, who has taught here for 20 years. "At this age their attention span for an activity is about 45 minutes, so that's about how long we'll stay in the orchard."

Working in pairs, the students examine each tree in the first two rows. Several weeks ago they drew the apple blossoms, detailing the flowers' anatomical features and showing a central "king" blossom surrounded by smaller satellite blooms. Today their task is to thin out the Braeburn crop by pinching off the stalks bearing smaller apples while preserving the larger fruit that has developed from that king blossom.

Eleven-year-old Maria Garcia explains why they need to destroy so many of the developing fruits. "We're taking out apples that are too close to each other," she says. "They have to be at least eight inches apart so they can get more nutrients and so—when the wind blows—they won't bump into each other and get bruised."

Welcome to what Alexander calls his "extended classroom." On a single acre planted with 500 apple trees, his students study life science, earth science, mathematics, economics, agriculture—even art. It's an ideal outdoor science laboratory, Alexander says, because the questions they are investigating are vitally important to the region's economy. Close to 60 percent of the 450 students in the elementary school come from families that depend on agriculture for their livelihoods. Ask the 21 students in Alexander's class how many have horses at home and about 15 hands go up.

apple of his eye

So close to Canada that the red maple leaf flies alongside the Stars and Stripes outside one town-center store, the small community of Tonasket sits on the banks of the Okanagan River in north central Washington. Pears, cherries, and peaches thrive in the long, hot growing season east of the Cascades, providing they receive adequate irrigation. The most important harvest, however, is the apple crop—the Galas, Golden Delicious, Cameos, Braeburns, and Fujis that arrive every fall to supermarkets across the nation.

Alexander saw an opportunity to teach his pupils about their community's agricultural heritage. Since 1982, he had envisioned planting a small orchard on the hill above the school. Six years later his teaching union, the Washington Education Association, awarded him a $16,000 grant to make his dream a reality.

"I wanted to create hands-on teaching about what we do in the valley," he says, "to say we're going to learn science through working in the orchard and taking care of a few apple trees."

In his mind's eye Alexander had seen a traditional orchard, spaciously planted with around 20 large apple trees, but after consulting with an advisory board of local experts, he discovered this vision was hopelessly outdated. Instead the group decided on a high-density planting of 500 dwarf apple trees, watered by the latest in high-tech irrigation systems, supported by trellis wires and surrounded by a 12-foot deer fence. Here, using organic farming methods, his students observe the growth cycle of six varieties of apples and investigate the relationships between climate, insects, fertilizers, sprays, and the resulting fruit crops.

The fifth-graders learn math skills as they figure out how much of an active ingredient to put in their organic sprays. They tend to the trees throughout the growing cycle and supply data to a Washington State University research project. At harvest time the students packed and sent out 140 gift boxes of apples, a commercial venture that brought in $2,500. As well as funding the upkeep of the orchard, the profits funded $500 scholarships for two Tonasket High School seniors heading for college to study natural resource management.

Tonasket students' inquiries involve them in studies of life and earth sciences, mathematics, art, economics, and—vital to the region's economy—agriculture.

"One thing we're impressing on them is that farming is just like any other industry nowadays," Alexander says. "You have to utilize technology to be successful. It's not the same as when their grandparents were farming, so they need a good science background and a good technology background to be successful."

A grant of more than $10,000 from the Bill & Melinda Gates Foundation helped pay for computers and software for the class. The fifth-graders could now supplement their observations of nature with information they found in encyclopedia programs and online library resources. They also began learning how to analyze data using spreadsheets.

Another grant of $17,000 from the Digital Blackboard Association allowed Alexander to spend two days a week developing an extensive curriculum for the project and putting it online. It took a year to write the first lessons, and he plans to add several more this summer. Teachers throughout the world can log onto the orchard Web site (www.orchardproject.org) and find learning activities about everything from cell structure and plant biology to climate and electric motors.

All the lessons on the Web site are connected with the orchard, but even teachers who don't have access to a garden can use many of the activities to bring science alive for their classes. To learn about cell structure, for example, students can examine cells from their own cheeks under a microscope and compare them to cells from an onion skin. To learn about climate, they can construct an artificial climate inside an aquarium using simple materials like paper, water, and salt. An experiment that involves growing pole bean seedlings indoors makes it easy to study plant growth, even in the heart of the city.

And what student wouldn't enjoy a math lesson that involves cooking apple crisp?

fertile grounds for inquiry

At the beginning of the year, Alexander supplies most of the questions, suggests hypotheses, and teaches his classes about scientific inquiry methods. Guiding his students through each step, he shows them how to make accurate observations and find the most useful information sources. But by the end of the year, he says, the young scientists have moved into the driver's seat.

"Once they understand that in an organic orchard you are trying to create a balance, they start really looking for that. They realize that you are seeking a balance between the good insects and the pests so if they start to see a lot of insects in one area and none in another they will start investigating on their own, looking at weed control maybe. They see a problem and say, 'Let's get that fixed.' That's one of the most rewarding things for me—when they're off investigating on their own."

Mayte Ortega was one of the first in the class to see the telltale holes that signaled the presence of the codling moth—a pest that bores into apples and eats the seeds. After researching possible remedies, the class found a trick that prevented the moth from breeding in the trees.

"The male moth finds the female through her scent," Ortega says. "So we put these little strings there, these little smelly strings to confuse the moth. That way he can't find a girlfriend, and she can't lay eggs."

The orchard offers a multisensory learning environment that helps children to absorb information no matter what their learning style, Alexander says. Students with learning difficulties participate in all the outdoor activities and experiments. When it comes to written work and projects, he modifies the lessons to meet students' abilities, while still presenting some challenges.

Alexander says the inquiry method is more time-consuming than direct teaching methods that emphasize lectures and individual seatwork—especially when working with larger classes. Yet, learning becomes more enjoyable for both teacher and students, he says, and students can make tremendous intellectual strides.

"It's good because you're learning something out of the orchard, not just out of the book," says student C. J. Ayers. Classmate Aaron Arlotta adds, "The best thing is that when you're done with working on it, you get to eat it."

When the bell rings, it's Larry Alexander's turn for lunch duty, so he spends the first half-hour supervising in the canteen. When it's his chance to eat, he reaches into his brown paper bag to produce—you've guessed it—one crisp, red, perfectly polished apple.

Helen Silvis is a Portland-based freelance writer.

QUESTIONS TO CONSIDER

- **Are we dreaming too big?** If your vision for an outdoor science laboratory involves large spaces, sophisticated technology, and advanced scientific expertise, you're probably going to need help from the community. Where are your likeliest sources of support? Find out if there are businesses and individuals in your community with the interest and ability to help out with funding, planning, professional guidance, mentoring, and volunteering.
- **Do any of our goals dovetail with those of potential partners?** Agriculture drives the economy of Tonasket and its region. Larry Alexander's goal to teach science in a context that his students would recognize from their everyday lives—the apple orchards—is of keen concern to the community. After local businesses stepped up to help with everything from funding to designing the orchard, support for the project spread to industry moguls and education philanthropists like Bill Gates, who donated computers. Tonasket students use the computers to share information about their community and environment with students on the other side of the Cascade Mountains.
- **Are there still other ways to fund our project?** You don't have to depend entirely on grants and gifts to keep your project going. Larry Alexander's students started up their own small business, selling the choicest apples in gift boxes for Mother's Day and directing proceeds to the orchard and a college scholarship fund.

Along the Inquiry Continuum

Like king blossoms on an apple tree, the inquiry learning experiences in Larry Alexander's online curriculum are some of the most fruitful. When students ask questions, hypothesize, undertake hands-on activities, investigate, analyze data, and report their findings, they are actively engaged in learning.

While inquiry may not be written into the entire curriculum, many of the lessons can be infused with greater degrees of inquiry learning. Below are two sample lessons adapted with permission from the Tonasket Orchard Project Web site (www.orchardproject.org). We've offered tips on how to enhance the inquiry in these lessons and encourage you to come up with some of your own ideas!

In the activity, Stem and Root Growth Regions, students predict the pattern of growth of a pole bean plant. While steps are prescribed, students are introduced to a key aspect of inquiry: hypothesizing. Asking students to hypothesize engages them in the topic and helps them to think abstractly and draw on their previous learning. Comparing their hypotheses with the results they observe in their inquiry compels them to think through their methodology: Were test conditions right for revealing what you wanted to observe? Were all variables controlled appropriately?

STEM AND ROOT GROWTH REGIONS

Objective: Students observe growth regions of plants.

Materials: black marker, ruler, pole bean seeds, plastic cup, soil, and water

Discussion: After fall harvest, apple leaves turn color and begin to fall off the tree. Next season's buds have already formed and, in the spring, will grow into blossoms, stems, and leaves. The tissue in plants where growth occurs is called growth regions. Growth regions of plants can be found at the tip of stems, roots, and buds. The small cells near the tip create new cells. As the new cells grow, they become larger and longer. Roots and stems grow longer and buds develop. In this experiment, you will observe the growth of both stems and roots.

Procedure: 1. Plant the pole bean seeds according to the package instructions. Water the same amount daily. **2.** When the pole beans are about three inches high, use the black marker and make a mark on the stem 1/2 inch below the top leaf. Make four more marks down the stem, each mark 1/2 inch apart. **3.** Draw a picture of the pole bean and label your marks 1, 2, 3, 4, and 5. Make a prediction about the growth of the stem sections and write it on your drawing. **4.** For five days, measure and record each stem section. **5.** Which section grew the most? Do your results compare with other students' results? Was your prediction accurate? If not, why?

Inquiry Tips:

- Ask students to explain why the plants should be watered the same amount daily. This can prompt their thinking about controlling variables.
- While some plants grow from their tips (dicots), like apple trees, pole beans, and snap peas, others grow from their base (monocots), like grasses, lilies, and orchids. Invite students to plant chive or onion seeds (monocots) and follow the same procedures as for the bean activity. Ask students what they've observed about the growth regions of these plants. Do results differ from those they observed in the pole bean inquiry? In what ways?
- To introduce this activity, ask students the open-ended question: Where on plants does new growth occur? On the tips, in the middle, at the base? How can you find out? Offer a variety of seed types to ensure that some students select monocots and some dicots. After the plants have been marked and given time to continue their growth, students can see that growth regions differ between plants that grow from their tips and those that grow from their bases. By prompting students to hypothesize and then test their conjectures, you stimulate their sense of discovery and understanding of inquiry.

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SEE TROPISMS, PAGE 8

ALONG THE INQUIRY CONTINUUM

TROPISMS,

CONTINUED FROM PAGE 7

In the lesson, Tropisms, students study photosynthesis and design an inquiry activity to illustrate the three types of tropism: phototropism, the bending toward light (leaves and stems); hydrotropism, the bending toward water (roots); and geotropism, the bending or growth away from gravity (stems).

Designing scientific investigations is at a point on the inquiry continuum where students are in charge of much of their own learning. Researchers have found that deep learning is embedded in purposeful activity, when minds, hands, eyes, and ears are interacting with phenomena. Even young students, like Alexander's fifth-graders, can design and conduct hands-on investigations. These experiences can be some of the richest for critical thinking, teamwork, and learning by doing.

TROPISMS

Objective: Students will devise experiments concerning phototropism, hydrotropism, and geotropism.

Materials: pole bean seeds, soil, plastic cups, and water

Discussion: Tropism is a bending movement in living things caused by an outside stimulus or signal. For example, plants bend toward light as they grow. The bending can be very slow, taking from hours to days to complete. In plants, there are three forms of tropism: phototropism, the bending toward light (leaves and stems); hydrotropism, the bending toward water (roots); and geotropism, the bending or growth away from gravity (stems). Devise an experiment to demonstrate each tropism.

Procedure: 1. Plant the pole bean seeds. Be sure to plant enough for each experiment. **2.** Working with a partner, devise an experiment to demonstrate each tropism. **3.** After the experiments are over, write a report including the definition of each tropism, a description of each experiment, and the results.

Inquiry Tips:

- Before planting, ask students to consider how they will design their inquiry activity to illustrate each type of tropism. Encourage them to think of the "unknowns" and how the answers to unknowns can be found. Can you solve for more than one unknown in a single experiment? (They must control all variables but one in each experiment.) Which of these three types of tropism might be the most difficult to observe? How will you need to design your inquiry to reveal it? (To observe hydrotropism, students might need to use see-through containers.)
- Ask students: What are the consequences for the plant when it must respond under stress to one of these three types of tropism? For instance, once the pole bean is three inches high, a student might set its container on its side—keeping all other variables constant—and observe any changes in its growth behavior. Geotropism might cause the stem to bend upward, growing thicker at the bend to support the weight of the plant. This can prompt a discussion about how the plant must redirect its energy to the area of the bend and what consequences this might have for it.

— Denise Jarrett Weeks and Eric Blackford

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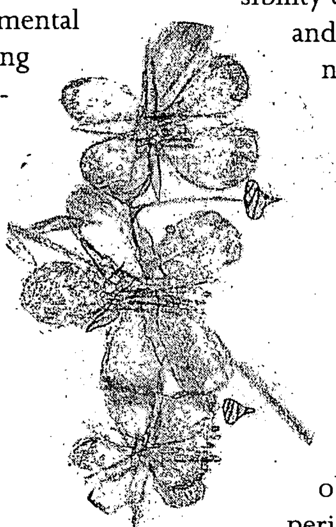
SCOPE, CONTINUED FROM PAGE 3

learning grounded in place

Moving inquiry out of the classroom and into the world makes the most of students' curiosity and interests. Inquiry-based science activities that are grounded in environmental concerns engage students not merely as future voting citizens but as authentic members of the community with "the capacity to effect change" (Stapp, Wals, & Stankorb, 1996).

In fact, there is evidence from a recent study that activities grounded in environmental issues enhance learning in all areas of the curriculum, including science (Lieberman & Hoody, 1998). Researchers looked at programs in multiple schools and states in which teachers and students used the environment to integrate learning across disciplines. The schools that participated in these programs demonstrated a number of positive outcomes, including increases in students' achievement in mathematics and science (Lieberman & Hoody, 1998).



The students also demonstrated a higher degree of enthusiasm for their work and increased engagement in the activities. Connecting science to complex environmental problems from their local communities demonstrates to students that what they are learning is important. As one high school teacher pointed out, "[Students] need to be involved in something that is bigger than they are... It counteracts a lot of discouragement and negative sort of dismay about our world."

In his book, *Ecological Literacy*, David Orr (1992) advocates an interdisciplinary approach to education that is centered on the question "What will people need to live responsibly and well in a finite world?" His vision for education teaches students a sense of connection to the whole environment in which they live. This connection involves a knowledge of ecology and their place in it, and a sense of responsibility and stewardship, and the practical skills necessary to act on their knowledge.

One of the models that Orr uses to illustrate his ideas is Thoreau's *Walden*. "For Thoreau, Walden was more than his location. It was a laboratory for observations and experimentation; a library of data about geology, history, flora, and fauna; a sense of inspiration and renewal; and a testing ground for the man. *Walden* is no monologue, it is a dialogue between a man and a place" (Orr, 1992).

This example shows the rich learning possibilities that can happen when students take their inquiries outdoors. However, an idyllic setting such as Walden Pond is not the only place such learning can happen—similar opportunities are present in playgrounds, gardens, creeks, and parks. Any outdoor setting can be a source of endless questions in which students can get directly involved and pursue a better understanding of the world in which they live.

Jennifer Stepanek is coeditor of Northwest Teacher.

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STUDENT SCIENTISTS TEAM UP WITH THE PROS

STORY AND PHOTO BY Amy Sutton

MASTERING INQUIRY PREPARES students to work with scientists and to tackle pressing environmental tasks in the Hood Canal watershed.

BELFAIR, WASHINGTON—Throwing 90 salmon carcasses into shallow streams in the Hood Canal watershed, then tracking the movements of the carrion for weeks, may be an odd—and odorous—pastime, but student Stefanie Howard can explain her fascination. "When a salmon decomposes, it acts as a mother log," says Howard, a junior at North Mason High School. "Macroinvertebrates and other creatures feed on it, helping fertilize the soil" in turn. The rotting carcasses, mimicking the life cycle of salmon, which die after returning upstream to spawn, "are important links in the food chain—the circle of life."

Howard designed this science investigation to enable her to track and measure the movement of the dead salmon, data that might indicate how the carcasses are used by creatures in the area. Like her classmates, Howard learns science by conducting investigations. Her teacher, Karen Lippy, is a veteran science teacher at the school district's Hood Canal Watershed Project Center. Lippy uses the rich wetlands nearby as a context for teaching science. In her course, The Aquatic World, students learn physics through studying tides, chemistry through analyzing water, and ecosystems through examining organisms, relationships, and energy flow. They also learn science through service-learning projects. While three science courses are required for graduation, it is not uncommon for North Mason students to sign up for four, five, or even six science courses so they can pursue service learning through the watershed projects.


Wetlands are rich learning grounds for students studying the aquatic world.

A narrow saltwater inlet extending between the Olympic and Kitsap peninsulas, Hood Canal ends at the small town of Belfair. The Skokomish and other Native American tribes relied on the bounty of Hood Canal for generations, harvesting salmon, clams, and oysters for subsistence. Logging in the 1800s and later development diminished forests and contaminated waterways, affecting habitat quality. In the 1980s, high bacteria levels shut down the shellfish harvest altogether and today's salmon have lost 40 percent of their habitat.

Students at the center take on projects that address community concerns. Each year, students provide about 7,000 hours to state and local agencies in monitoring and collecting data from the watershed, Lippy estimates. Recently, students analyzed conditions in the Tahuya State Forest on the Kitsap Peninsula for an upcoming state timber sale. In another project, students determined the best footpath material for limiting sediment runoff. While it cost the state Department of Natural Resources (DNR) $10,000 in staff time, transportation, and materials, the students' work was valued at $250,000. Equally important, students learned how a healthy watershed functions and observed the impact of their efforts. "By learning science through projects, students are empowered," says Lippy. "They know they have the skills to learn anything."

Junior Kelly Cloud notes that "DNR was impressed that students did this. We saved them a lot of time in helping them plan for selective cutting." Classmate Heather Bartels adds, "You feel like you're making a positive difference."

The Hood Canal Watershed Project Center was built on land donated by pioneer Sam Theler. Grants through DNR and other agencies, and land contributed by state Department of Fish and Wildlife, have helped to make the 135-acre wetland and learning center the focal point of the community, says Lippy. Five distinct kinds of wetlands can be found there, and a system of trails and interpretive signs encourage visitors to explore the various habitats. The high school and two elementaries integrated environmental education across their curricula, using the wetlands and facilities for learning activities.

Lippy, who's won multiple awards for teaching, advocates an integrated, project-based approach as a way for students to learn science deeply. Encouraging students to slow down and look closely at the world, Lippy uses the outdoors as a medium for teaching observation and analytical skills. At the high school, the science curriculum's integrated model uses common science strands, such as force and motion. "Whether you're looking at tides or plate tectonics, it's a huge concept" that teachers revisit many times, Lippy says. The focus on common strands and applying this learning in real-world contexts means that "what students know, they know very well because they're immersed in it."

disciplined discovery

Lippy typically oversees about 50 projects a year. She screens proposals from state and local agencies and other "contractors" to ensure that the necessary support is available for students to effectively carry out the work. Students embrace the high expectations their teacher and "clients" have for their performance in scientific knowledge, project design, investigative methods, reporting, and other aspects of scientific inquiry. Lippy values working individually with students, noting the importance of personal relationships in teaching. She guides rather than directs students through their projects, serving as a resource in suggesting an idea, a book, or a good person to consult.

For student Stefanie Howard, Lippy's guidance allows her to direct her own learning, asking questions as needed, such as "how to deal with unexpected happenings"—something that cropped up during her salmon project. Howard had mapped the stream sites, where she'd dropped the carcasses, using Global Positioning System (GPS, a satellite-based navigation system), and Global Information System (GIS, a computer mapping program). She found that the carcasses moved considerably, some disappearing altogether, then reappearing later. The disappearances "messed up the variables," she says, leading her to discuss the role of data consistency with Lippy. Howard conjectures the salmon were carried off by coyotes or dogs, but, next year, she hopes to set up surveillance cameras to determine conclusively which animals are taking the dead fish.

Even when projects are less student-directed, Lippy sees opportunities for students to hone their independent learning and inquiry skills. Students write reflections in journals regularly, assimilating what they're learning. They shape their work into a final product for a specific audience, whether a written report or a visual display of findings. They learn to go to different sources for information, including asking scientists questions. "Even when students don't initiate projects, they have a lot of decisions to make," Lippy observes. For example, "Water quality analysis requires critical thinking" by making students justify their findings logically.

Having completed half a dozen courses and two summer internships with the Watershed Project Center, senior Pete Allard speaks knowledgeably about data collection and analysis. He taught 10 crew members to use a clinometer to measure trees and snags, and to take core samples for the Tahuya State Forest timber sale project. Allard operated GPS and GIS instruments to collect and represent the data and to create detailed maps for the timber sale. Allard and his crew understood the importance of accurately mapping the land so that trees and snags vital to the habitat would be left standing. "I learned the difference between collecting 'good' data and 'quality' data," Allard explains. "You may have good data, but it has to have quality for it to be substantially useful." Time is an important factor, Allard adds, "as well as how precise you are. If you're sloppy, you can't hold the data to a microscope and pick it apart."

science and stewardship

The students' investigations often raise issues and ideas in other areas, such as social and conservation concerns. For example, students mapping the lower Hood Canal watershed determined there were 22 miles of stream, 16 more than state records indicated. "This is critical coho salmon habitat the students documented," Lippy notes. Another group of students discovered Stream 504, a forgotten creek that flows through Belfair in culverts. Students used handheld electronic data recorders and flow meters to collect data on the stream, particularly in areas where it could collect oil runoff or other pollution. While Lippy is careful not to set students up as environmental advocates, the lessons aren't lost on them. They understand that their work on behalf of the ecosystem isn't always welcome. When student Heather Bartels was challenged by a wary landowner, she stood her ground. "I knew I had legal rights to collect the data" from the stream passing through his land, she says.

Lippy sees many benefits in tying these types of community-based projects to inquiry science. Students gain independence from knowing they can do their own work, while community members learn to view teenagers as positive contributors. Most important, Lippy knows she is serving all students: "Some students are going into science or doing exceptional science at the postsecondary level, while others are studying science who never would" otherwise.

This fall, Pete Allard will be the first in his family to attend college. He'll take with him three scholarships he earned from his watershed work and college-level credits from the center—he's setting his sights on a master's degree. The center "motivated me to pass other classes," Allard says. While many of his college classmates will get their introduction to environmental science from a textbook, he'll arrive with real field investigations under his belt. Those experiences awakened a passion for science that will likely serve Allard—and the environment—very well in the years ahead: "People take wild salmon for granted, but if you lose salmon, you lose so many other animals that keep life going—seals, birds, bears, coyotes. Salmon keep the streams alive and healthy." And inquiry-based learning can keep science alive and relevant for novice scientists.

Amy Sutton is a math and science resource specialist for NWREL and an advocate of schoolyard gardens and habitat laboratories.

QUESTIONS TO CONSIDER

- **Are our students ready for this level of independence?** Students often aren't ready to jump straight into project-based learning, says Karen Lippy. Teachers will want to cultivate their students' sense of responsibility every day, by engaging them in active learning that requires them to make meaningful decisions, work with others, and communicate their thinking.
- **How broad should community involvement be?** Community members contributed grant-writing and marketing skills to the Watershed Project. Employees from local businesses drive students to project sites and the larger community takes pride in seeing students' achievements. Consider all sectors of your community as potential sources of assistance, and invite those whose expertise, interests, and abilities best match the needs of your students. Share project news with your school public relations office and local media.
- **What are our expectations for student success?** Community partners who work with students from the Watershed Project rate their performance in 18 areas, from teamwork, listening, and safety to quality of products and services. From the start, Lippy conveys to students and partners the difference between acceptable and substandard performance. She also keeps parents informed.

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SCHOOLYARD SCIENCE TAKES ROOT

STORY AND PHOTO BY Suzie Boss

WHETHER A RAISED GARDEN, riparian zone, or weather station, rich opportunities for scientific investigations can abound right on school grounds.

While the bulk of the work often falls on teachers' shoulders, parents can be enthusiastic helpers when they see their child flourish in the rich environment of the schoolyard garden or outdoor science laboratory.

PORTLAND, OREGON—At Chief Joseph Elementary School in North Portland, a low cover of clouds keeps the morning air cool. It's perfect spring planting weather, and Eric Olson's fifth-grade students are itching to get started. For the past several weeks they have been venturing outdoors in teams of three or four to pull weeds, work compost into dirt, and dump wheelbarrow loads of wood chips along the narrow, child-sized footpaths of the school garden. Today they'll finally get to press seeds into soil, starting a new cycle of life.

But first, these eager gardeners take time to plan not only what they're planting, but why and how. Their outdoor investigations will give them opportunities to raise questions and test hypotheses. If they happen to have fun, get a little dirty, and polish their teamwork skills in the process, all the better.

How did garden science take root in this urban setting? Olson, a longtime believer in the power of inquiry to teach science and winner of a Presidential Award for Excellence in Science Teaching, also happens to be a passionate gardener. He has been nurturing this school plot for a decade, giving city kids a chance to count the legs on a ladybug, taste the peppery leaf of a nasturtium, or watch an earthworm make its way through the soil. Because the school garden is so handy—right outside the classroom doors, tucked between the school building and the sidewalk—students can make repeat observations without the expense or scheduling challenges of field trips.

outdoor learning labs

To give students a chance to do real science, many other educators are also making creative use of outdoor settings where students can conduct investigations without ever leaving the school grounds. Models for outdoor learning labs vary widely, from the simple garden beds used effectively at Chief Joseph School to more elaborate campus environments that may involve ponds or other water features, raised garden beds, native plants, bird feeders, weather stations, or habitats designed to attract wildlife.

Several organizations offer support to educators looking for models for building and using outdoor learning labs. School gardens are an increasingly popular approach; more than 1,000 schools nationwide have joined the Garden in Every School Registry maintained by the National Gardening Association (www.kidsgardening.com). Another 1,100 schools have launched Schoolyard Habitat projects, organized by the National Wildlife Federation (www.nwf.org/habitats/

schoolyard/). Classroom FeederWatch (CFW) projects, developed by the Cornell Lab of Ornithology with funding from the National Science Foundation, use students' natural curiosity about birds—the most numerous of the vertebrates—to get them engaged in the inquiry process. Curriculum materials explain how to frame a question for field research. The project also enables students to share the results of their investigations with other young scientists on a project Web site (http://birds.cornell.edu/cfw/about_cfw/cfw_details.html).

parent support

In many schools, parents are providing the muscle to develop outdoor spaces for learning. Soon after Trail Wind Elementary School opened in Boise, Idaho, in 1997, teachers were surveyed about their need for materials. "They had textbooks, but nothing for hands-on teaching," says parent Susan Velikoff. "That was their top need." Parents planted the idea of creating an outdoor classroom on a one-third acre site adjacent to the school building. They assembled a committee, enlisted more volunteers, and the idea took off.

After a year and a half of planning, research, fundraising, and work with a landscape architect, the outdoor classroom is now the pride of the school. Paths meander alongside raised garden beds, a pond, native plants, an outdoor amphitheater, weather stations, and bird feeders. "Our teachers do tons with science out there," says Principal Debbie Toy, from having students observe insects to mapping the time of day on a sun clock to studying soil samples under a microscope.

Learning in Trail Wind's outdoor classroom isn't limited to science. Students also go outside to write haiku or work on art projects. The school counselor uses the peaceful setting for conferences. "But science is what it's used for the most," says Velikoff. Primary students, for instance, went to the outdoor classroom to release butterflies they had raised from the pupa stage. Right before their eyes, they discovered the answer to their question: What do butterflies eat? "They watched them fly right over to the butterfly garden that they had helped plant, and drink the nectar from flowers," recalls Velikoff. "This is the kind of learning that kids remember."

Parents also play an important role in sustaining the school garden at Edwards Elementary School in Portland. This year-round school happens to be located adjacent to a community garden maintained by the city parks department. Over the years, many teachers have taken classes outdoors to plant flowers and vegetables. Recently, the staff started evaluating how to align those fun activities with the science curriculum, "so that what we're doing in the garden is more structured, more cohesive," explains Principal Mary Patterson.

A challenge, Patterson admits, "is that teachers' plates are very full already." And while many teachers consider outdoor science inquiry a wonderful, worthy idea, "there are many competing wonderful ideas out there." Parents can provide the support and energy to keep the garden growing and teachers from feeling overwhelmed. Edwards School has a "garden parent" volunteer assigned to each classroom to assist with outdoor projects. In addition, two parents recently went through a wildlife habitat training program provided by the 4-H program in Multnomah County. "You don't have to create curricula or processes from scratch," Patterson says. "If you have motivated people, connect them with good resources that are already available."

As their newest garden project, a team of Edwards parents has volunteered to set up worm bins so that refuse from the cafeteria can be composted. Knowing that parents will build and maintain the worm bins, teachers are free to plan science inquiry and math projects that will make use of the resource. It's the kind of undertaking that reminds Patterson to go slowly. "Choose one thing to accomplish and do well within a year," the principal recommends. Success with one outdoor project "will spark staff interest and parent support. And you can grow from there."

real science

It doesn't matter whether teachers use a garden plot, riparian zone, or birdfeeder to get students curious about science. The same principles of scientific inquiry apply in all settings.

Olson, for example, has used the inquiry method to guide students through projects involving everything from worm bins to wood duck nests to cornstalks.

Before he turns students loose in the school garden for their spring planting project, he asks a few questions of his own to make sure they understand the basic elements of scientific inquiry. In Olson's class, students pose questions on which to base the design of their investigations. They plan and conduct experiments, making close observations and measurements and recording data. Because planting takes place near school year's end, they pass on their careful recordkeeping and hypotheses to next year's incoming students who will complete the experiments.

As the Classroom FeederWatch Web site explains, "Asking a good question, one that can be answered by carrying out experiments, is often challenging." Students new to the inquiry process may pose questions that are too vague to answer. Alternately, they may ask questions that others have posed and answered already. If the answer can be quickly found in library references or on the Web, it probably isn't the best question to pursue in an investigation. The teacher's role in this kind of activity is to "intervene at the right time, to prompt the right questions, and to steer the learning process into deeper waters of experience and advanced thinking," explain Robin C. Moore and Herb H. Wong, authors of *Natural Learning: Creating Environments for Rediscovering Nature's Way of Teaching* (1997).

"Garden science is no different from any other science," Olson reminds his class. "Try to change only one variable at a time, so you'll know what has worked."

From the animated discussion that ensues, it becomes clear that fish heads will play a role in several teams' investigations. As the class has already learned, Native Americans used salmon as organic fertilizer, planting fish heads along with their corn crops. A local grocer has donated the leftovers from salmon filets for Olson's class to use. One girl says her team wants to test whether planting the fish heads at different depths will affect the growth of corn. "So you're investigating where plants use fertilizer then," Olson adds, "down at the root, or closer to the top of the plant." Another team chooses to investigate whether adding more fish heads to a planting site will yield taller corn. Again, Olson echoes back the description, stressing the variable under investigation: "So you're studying how different quantities of fertilizer affect plant growth."

Once he's satisfied that the investigations are well designed and described in clear language that any other scientist could duplicate, Olson signals that it's time to move outside. "The cafeteria staff has been nice about keeping these fish in the refrigerator for us," he adds, "but we can't keep them much longer. Let's get them in the ground." And so they're off—hypotheses in mind, shovels and yardsticks in hand.

Suzie Boss is associate editor of Northwest Education, *NWREL's quarterly magazine.*

Questions To Consider

- **Won't kids just "play around" in an outdoor setting without the structure of a classroom?** Inquiry strategies tap children's natural gift of curiosity, especially when they're exploring their everyday world. Asking questions, observing, recording, hypothesizing, designing investigations, working and talking together, and telling others what they've learned is usually all it takes to instill a motivational "structure" that keeps kids engaged, indoors or outdoors.
- **What topics should we teach in an outdoor laboratory?** The outdoors presents ideal integrated-learning contexts that raise important ideas in physical and earth sciences, mathematics, geography, social sciences, language and fine arts, technology, as well as career-based learning. An outdoor lab can be common ground where teachers of all subjects come together to collaborate on cross-curricular projects.
- **If we have a school garden, who'll take care of it?** While teacher Eric Olson oversees Chief Joseph's garden, parents are the primary caretakers of the garden at Edwards Elementary. If you need others to lend a hand, help interested parents and community members find the training they might need by, for example, pointing them to community gardening and wildlife habitat classes or to youth mentoring training programs. Identify a volunteer coordinator in your school to be liaison for parents and teachers so that everyone works toward the same goals.

books and materials available from THE CENTER'S LENDING RESOURCE COLLECTION

The NWREL Mathematics and Science Education Center's Resource Collection is a lending library of teacher-support material. Search the collection and request items from the Web site at www.nwrel.org/msec/resource/ or call (503) 275-0457. The only cost is to mail items back at library rate.

These sample resources are just a few of those available from NWREL that can help teachers and professional development specialists foster inquiry-based science learning, outdoors and in the classroom.

Excellence in Environmental Education: Guidelines for Learning (K–12)
North American Association for Environmental Education (1999, 2000)
With grade four, eight, and 12 benchmarks, these guidelines set expectations for performance in questioning, investigative and analytical skills, and environmental knowledge.

Ten-Minute Field Trips: A Teacher's Guide to Using the School Grounds for Environmental Studies (3rd ed.)
Helen Ross Russell (1998)
Whether your school grounds are hard-topped or naturescaped, the author shows how to encourage student questioning, observation, and thinking through classroom activities and frequent outside expeditions.

Taking Inquiry Outdoors: Reading, Writing and Science Beyond the Classroom Walls
Barbara Bourne, ed. (2000)
In these essays, elementary and middle school teachers share their stories of engaging learners in science through the environment, community, and reading and writing. The essays include graphic organizers, activities, and tips.

Active Assessment for Active Science: A Guide for Elementary School Teachers
George Hein and Sabra Price (1994)
This guide offers examples, ideas, and processes to help teachers develop and score their own assessments of inquiry learning.

Natural Learning: Creating Environments for Rediscovering Nature's Way of Teaching
Robin Moore and Herb Wong (1997)
By highlighting an urban school community that transformed asphalt into an "environmental yard," this guidebook shows how to use outdoor space to teach the whole child with the help of the school community.

Biology Is Outdoors! A Comprehensive Resource for Studying Environments
Judith Hancock (1991)
This high school–level guide provides teacher and student instructions, activities, and templates for conducting and assessing open-ended investigations in the schoolyard.

NWREL Science Inquiry Model™
www.nwrel.org/msec/science_inq/index.html
Explore this Web site for sample inquiry tasks, trait-based scoring guides, and other resources for teaching the essential traits of science inquiry. The Resources section links to the online book, *Inquiry Strategies for Science and Mathematics Learning*, and the video, "Why Won't You Tell Me the Answer? Inquiry in the High School Classroom." The science model is also featured on the PBS TeacherSource Web site at www.pbs.org/teachersource/whats_new/science/mar01.shtm.

Inquiry and the National Science Education Standards: A Guide for Teaching and Learning
National Academy of Sciences (2000)
Inquiry is central to the *National Science Education Standards*. This book illustrates how teachers can create standards- and inquiry-based learning experiences that enable students to develop their scientific understanding and inquiry abilities.

Atlas of Science Literacy: Project 2061
American Association for the Advancement of Science (2001)
To create inquiry activities that target key ideas in science, teachers can consult this guide to the AAAS *Benchmarks for Science Literacy: Project 2061*. Linked maps illustrate sequences of ideas that can lead to specific learning goals and connections across science, mathematics, and technology.

Learning Science Through Inquiry
Annenberg/CPB Channel (2001)
Professional developers and teachers can use this eight-part video series and accompanying support material to explore inquiry-based teaching and learning strategies for grades K–8.

AMY SUTTON
is a resource specialist for NWREL.

SEMINAL MOMENTS OF learning await in the outdoors, where young minds can alight on ideas and experiences that take them into the wonders of science.

At a recent meeting I attended, the facilitator asked us to share our memories of a positive science experience from our years as students. As I recalled events from my college and high school science courses, I found myself trying to remember the roots of my interest in science. Was it the time I sat in class listening to the radio as John Glenn's space capsule lifted off to circle Earth; or perhaps when I waited in the school gym for my polio vaccine, which my parents assured me was a remarkable event in medical history? Suddenly, a long-buried memory sprang to life: my first science fair! I was in the fourth or fifth grade, and I can still remember the thrill of actually being able to *do* science. Up until that time, science was basically something I read about in a textbook or observed as our class watched a science movie. Although I had always found the subject interesting, it wasn't until that elementary science fair experiment that I had an opportunity to conduct an investigation, collect data, think about the findings, and try to make sense of what I had learned. I was hooked!

The articles in this issue of *Northwest Teacher* provide strong evidence of the powerful effect "doing science" can have on students' learning and attitudes. Recently, we've heard from elementary teachers throughout the region who are struggling to continue to include science instruction in the school curriculum and schedule. With the emphasis of state assessments on language arts and mathematics standards, the science curriculum can be easily pushed aside in favor of more instructional time for those subjects that dominate state testing. However, it is important to remember that learning science involves much more than the acquisition of knowledge. When science is taught using the strategies and techniques that are exemplified by the stories in this issue, students not only learn important science concepts and processes, but also develop critical habits of mind.

A WORD FROM THE DIRECTOR

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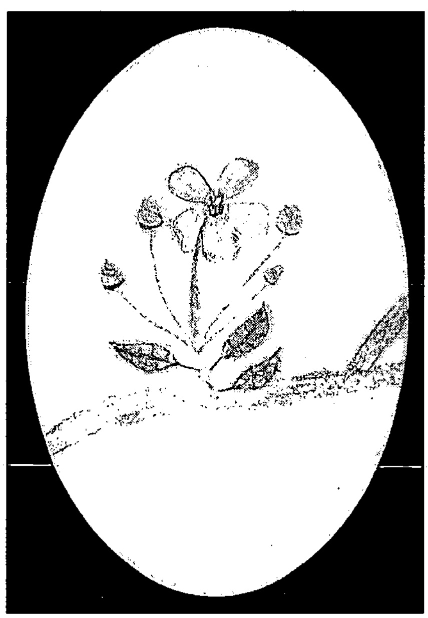

The 1996 *National Science Education Standards*, issued by the National Research Council, and *Benchmarks for Science Literacy: Project 2061*, published by the American Association for the Advancement of Science, include these habits of mind, recognizing them as essential components of scientific literacy in the 21st century. Attitudes, skills, and values such as problem solving, curiosity, honesty, skepticism, and openness are characterized as habits of mind, say the authors of the *Benchmarks*, because they "all relate to a person's outlook on knowledge and learning and ways of thinking and acting." When students learn science through an inquiry approach, they develop these important and broadly applicable habits of mind.

We hope these *Northwest Teacher* stories will remind you about the excitement of "doing science." They reveal some of the many wonderful things that are happening in today's classrooms—classrooms that are not defined by four walls, but ones that engage students in learning meaningful content and developing habits of mind in a variety of environments.

NORTHWEST
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A Math and Science Journal Devoted to Rigorous and Imaginative Learning

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