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ABSTRACT

This document is comprised of the four 1995-1996 issues of "Classroom Compass," a newsletter of the Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching. Each issue contains a "Resources and Opportunities" section, a reading list, excerpts from the National Science Education Standards, and learning activities. The reading lists included in these issues pertain to equity in science and mathematics education and classroom assessment. Miscellaneous background articles address design in the classroom and science and mathematics for all. The learning activities provided enable students to study the functions of the heart, pendulum motion, a design exploration that uses the story of the three little pigs, and a design exploration about power boat design. Excerpts from the National Science Education Standards provide information on science and technology across grade levels, assessment in mathematics classrooms, the world beyond the classroom, and environments for learning about science. (DDR)

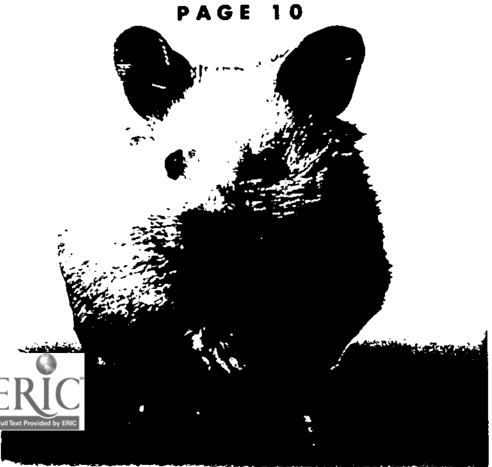
Classroom Compass, 1995-96

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

Classroom Compass

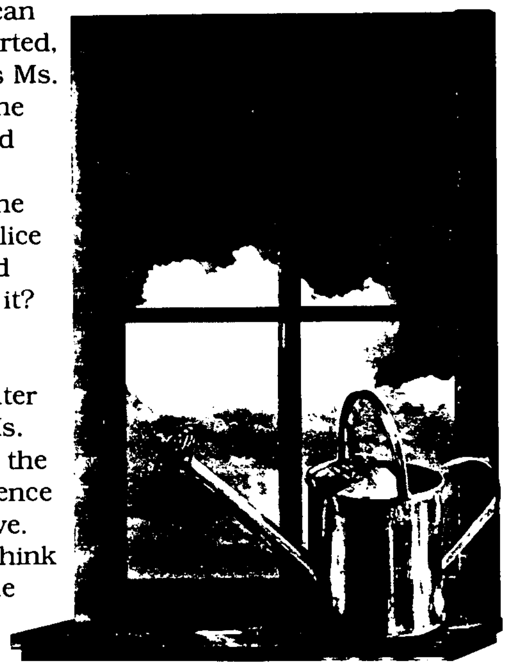
Fall 1995 • Volume 2, Number 1

HIGHLIGHTS



Where Did the Water Go?

Mary Alice was annoyed. The watering can had water in it when she left it on the window sill on Friday, but it was empty on Monday morning. She didn't have time to fill the can before class started, and. as soon as Ms. Wilson began the class. she raised her hand.



"Who used the water?" Mary Alice demanded. "Did someone drink it? Or spill it?"

No one had touched the water since Friday. Ms. Wilson realized the class had a science question to solve. "What do you think happened to the water?" she asked.

Jennifer had an ingenious explanation. "I bet Willie the hamster got out of his cage and drank it. We could prove it by covering the can and see if the water level goes down the next day."

"I don't think Willie can get out of his cage," said José. "Let's figure out a way to know what he does at night. Maybe we could put his cage on the sand table and see if he leaves footprints."

Before leaving, the class covered the watering can and smoothed down sand around Willie's cage. The water level remained the same and no little paw prints appeared in the sand.

"But wait," said Kahena. "Why should Willie get out of his cage? He can see the can is covered. Let's leave it uncov- ered and see what happens."

So the class again left the cage in the mid- dle of the sand table but left the cover off the can. It took several days for the water level to drop, but it did go down, and there were still no footprints in the sand. By this time, the children were willing to let go of their original idea about the water's disappearance, and Ms. Wilson suggested an alternative experiment: "Let's put a jar of water in the window sill and measure it each day with paper slips to see if we can learn

continued on page 2

Science and

Ms. Wilson found a way to help her students connect science to their lives. Years from now, many of them will still link their understanding of evaporation to their experiments with the watering can and the conversations that ensued. Understanding the whys and hows of that event helped the children build skills that will support them all their lives.

There is little doubt that the future will be filled with science and mathematics. Rapid advances in computer technology, the infusion of complex mathematics in economics, and the influence of science on health and medicine

Where Did the Water Go? *continued from page 1*

anything from the water's changes," she said.

After several days of observation, the students saw a pattern: the water was falling steadily but did not decrease the same amount each day. When they tried a differently shaped container, the rate changed. As the children worked toward developing an understanding of the influence of surface area and air temperature on evaporation rates, they discussed and predicted results of experiments they designed themselves.

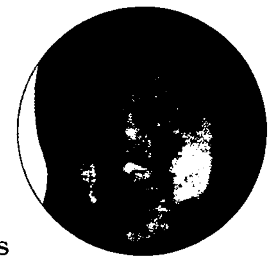
This scenario has been adapted with permission from the *Draft National Science Education Standards*. Copyright 1994 by the National Academy of Sciences. Courtesy of the National Academy , Washington, D.C.

are but a few examples from today's society. Once thought by some to be the realm of an intellectual elite, science and mathematics are part of everyone's life. Students' success as adults will be influenced by their ability to observe, interpret, and understand their surroundings. Education's challenge is to instill the underlying concepts of science and mathematics in all students so they can construct their own foundations and continue to learn throughout their lives.

Make It Real

To begin to build that lifelong foundation, students must view science and mathematics with interest and enthusiasm. Teachers can nurture intellectual excitement by linking classroom activities with real life. While some learners work well with abstract ideas, for most of us understanding is enhanced when it is linked to a familiar experience. While many textbooks and instructional activities provide interesting theoretical suggestions, taking those theories and applying them to student experiences can test a teacher's ingenuity.

Trips to the grocery store, a bicycle or rollerblade ride, making and spending money, or exploring the shapes of homes, local businesses and the school building—all have potential for mathematics questions. The environment within and outside the classroom (local streams and geologic formations, pet behavior, observations of the sun or the moon) can help convey the immediacy of science. A "star party" is a great way to engage students in observation and exploration of the night sky. If your school is connected to the Internet, hook into a meteorological site that provides reports of weather patterns across the country or around the world. Many excellent instructional materials pose questions and suggest activities that can be tied to the local environment. Build your lessons around them with a thought of how familiar and immediate they will be to your students.



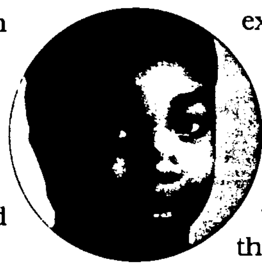
Questions Uncover Understanding

How do we know what students are learning? How do we know what they bring to the classroom? What are their thoughts and theories? Finding the right questions and the ways to ask them is the essence of the art of teaching. The structure of a teacher's questions determines the pace of a lesson, the direction inquiry will take, and the balance of autonomy between the teacher and students. Questions that probe for further explanations help students construct and articulate their understanding. They also help the teacher grasp what they understand. Ask how ideas fit with the observable evidence. Have they had other experiences that support their ideas? Do others have alternative experiences or alternative ideas?

Conversations should occur among students, as well as with the teacher. Student-based questions—questions they pose in discussions or to the teacher—provide insight to their understanding. Give them enough thinking time, "wait time," to reflect and gather a response. Students who can explain their

Mathematics for All

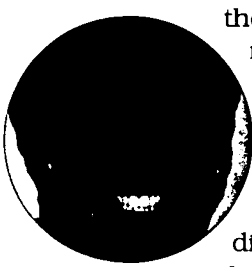
ideas may be able to present a concept in a new and more understandable way, for themselves and their classmates.



Small groups focused on a particular question can offer a safe environment for discussion and problem solving. A classroom with a level of comfort about ideas, reflection, and disagreement encourages curiosity and inquiry. Permission to speculate and contribute is one way of opening the inquiry of science and mathematics to all. Knowing Willie was probably not the water culprit, Ms. Wilson supported the students' exploration into his nocturnal habits. Without the permission to explore their ideas, the class would not have progressed to the next steps of looking at evidence, rethinking, and gathering new evidence. Everyone can benefit from the class's collective experiences and understandings of the world around them.

What to Teach?

One of the challenges of teaching mathematics and science is the breadth of subject matter. How can educators accommodate the call for "Less Is More" and adequately address the content of the disciplines? The authors of *Benchmarks for Science Literacy* state: "The common core of learning in science, mathematics, and technology should center on science literacy, not on an understanding of each of the separate disciplines." The authors note that learning experiences must include connections among science, mathematics, and technology, as well as the arts, humanities, and vocational subjects.



As an example, younger children can understand the relation between heart rate and exercise if they are given the time to explore. Drawing pictures of the heart or memorizing the names of the heart's chambers will not provide such depth or experience. The connections that link their learning to larger themes such as living systems (how hearts work inside living bodies), social issues (the effects of air pollution or smoking), or health (the influence of diet and exercise on the heart) are the beginning of real science literacy. Mary Alice's questions about the disappearing water could lead the class to an examination of weather patterns, energy and matter, or the importance of measurement in scientific inquiry. Ms. Wilson could choose any one of these avenues (but not all three!) to provide a larger picture for understanding evaporation. The definition of evaporation, while probably one outcome of the examination, is but a piece of the puzzle.

Equity in the Classroom

By using her questioning skills, giving the children's imagination free rein in the early stages of theorizing, and focusing their activity on one investigation, Ms. Wilson set the stage for scientific inquiry. The experiment, as it extended over time, gave the students the chance to reflect and discuss their ideas. Each child was encouraged to contribute, to bring individual theories, observations, and conclusions to the problem. By taking each child's response seriously and letting the students design the experiments to explore the problem, Ms. Wilson demonstrated respect for diverse backgrounds and experiences while acknowledging their different levels and abilities.

Our classrooms are filled with diversity. They challenge teachers who are striving to introduce all students to the excitement and power science and mathematics can bring. The *Curriculum Standards* from the National Council of Teachers of Mathematics (NCTM) say it well:

> "...today's society expects schools to insure that all students have an opportunity to become mathematically literate, are capable of extending their learning, have an equal opportunity to learn, and become informed citizens capable of understanding issues in a technological society. As society changes, so must its schools."

Ms. Wilson's story presents the basics of equity in its evenhanded acceptance of the children's ideas. Specific questions of ensuring participation ("How do I get more girls in the computer lab?" "How do I design activities that include my physically handicapped youngster?" "What about the wide range of abilities in my class?") are addressed in many publications from many different organizations. See the reading list, *Equity in Science and Mathematics Education* on page 10, for further ideas.

Benchmarks for Science Literacy by Project 2061 of the American Association for the Advancement of Science (AAAS). Published by the Oxford University Press. 1993.

Curriculum and Evaluation Standards for School Mathematics by the National Council of Teachers of Mathematics (NCTM). Published by NCTM. 1989.

National Science Education Standards by the National Research Council (NRC). Published by National Academy Press. 1995 (projected).

Science As Inquiry: Early Grades

The following excerpts (pages 4 and 7) are from a draft version of the *National Science Education Standards*. These particular sections present guidelines for the development of science inquiry skills from kindergarten to grade 12. The accompanying activities, "Howdy Heart" and "The Pendulum," suggest ways to foster student inquiry in the classroom.

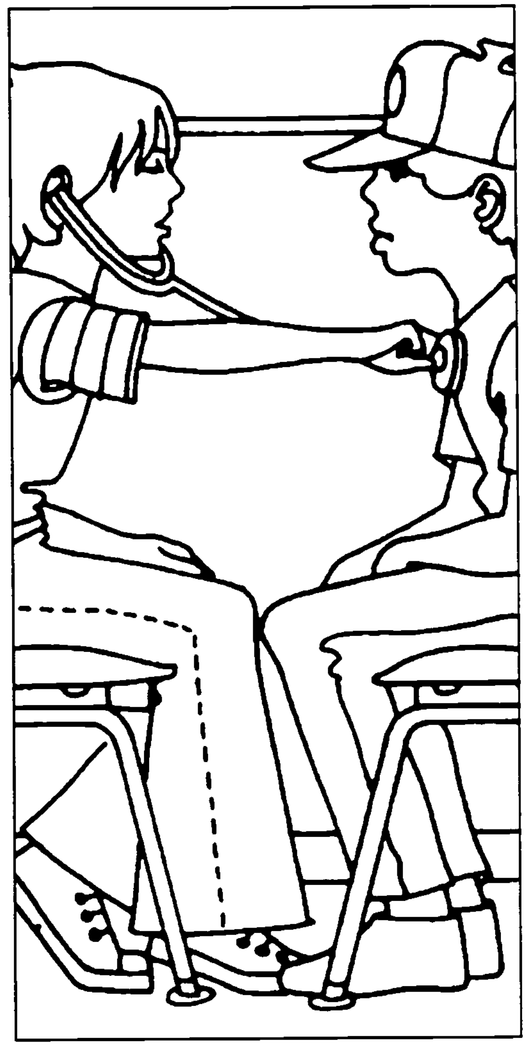
Content Standard for Grades K–4: Science as Inquiry

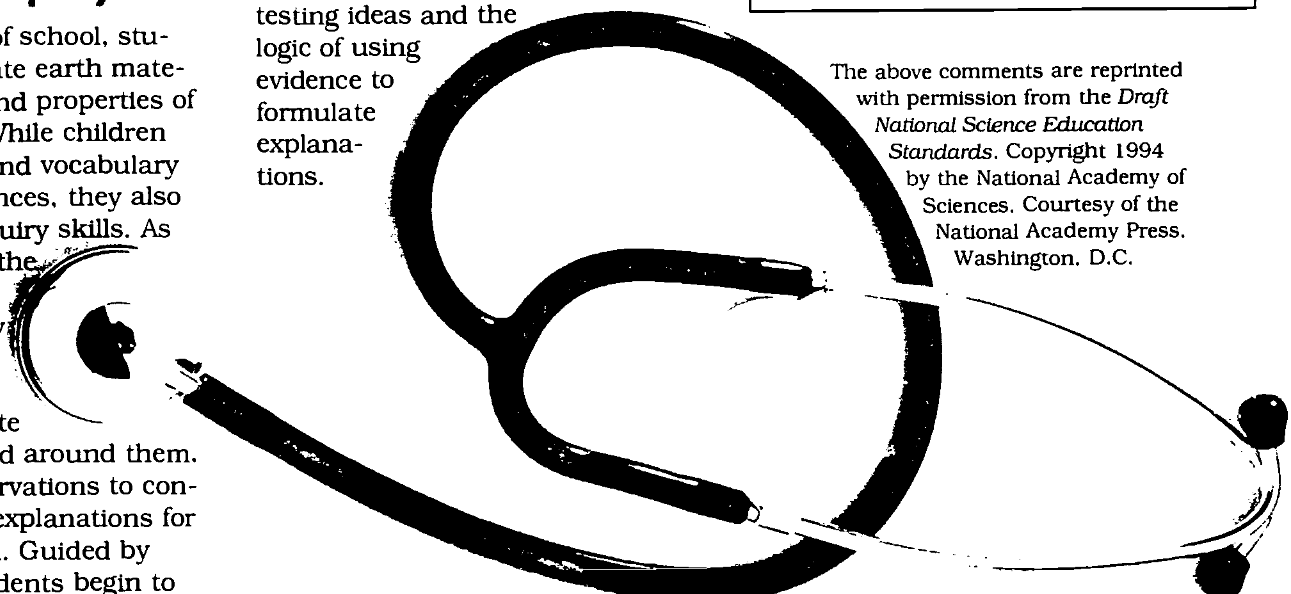
In the early years of school, students can investigate earth materials, organisms, and properties of common objects. While children develop concepts and vocabulary from these experiences, they also should develop inquiry skills. As students focus on the processes of doing investigations, they develop the ability to ask a scientific question, investigate aspects of the world around them, and use their observations to construct reasonable explanations for the question posed. Guided by their teachers, students begin to develop their science knowledge.

As part of the inquiry process, students should also learn how to communicate their investigations and explanations and those of others.

Although there is logic to the abilities outlined in this inquiry standard, a step-by-step sequence or "scientific method" is not implied. In actual practice, student questions may arise from their previous investigations, planned classroom activities, or questions they ask each other. For instance, if children ask each other about how animals are similar and different, an investigation might arise into characteristics of organisms they can observe.

Full inquiry involves asking a simple question, completing an investigation, answering the question, and presenting the results to others. In general, elementary students are developing the physical and intellectual skills of scientific inquiry. They can design investigations to try things to see what happens—they will focus on concrete results of tests and even entertain the idea of a "fair" test, a test in which only one variable at a time is changed. They may have difficulty with experimentation as a process of testing ideas and the logic of using evidence to formulate explanations.





Howdy Heart

An Activity for Younger Children

This activity allows students a peek into their own bodies and gives them a way to quantify their observations. As an example of "Less is More," it allows a young child access to the basics of scientific investigation through a simple and immediate activity. In later lessons, connections could be made to understanding the human body, ways of presenting data, or information on health and fitness.

Questions will emerge as the students explore with the stethoscopes.

- **What sounds did they hear as they examined the room?**
- **What situations increase heart rate?**
- **Does anyone have an example from personal experience?**
- **We see that exercise increases heart rate, what else (what other *variables*) might affect it?**
- **How could we test for these other *variables*?**

The comparison of resting and active heart rates provides an opportunity to introduce the ideas of *variable* and *controlled experiment*. Explain that the experiment started with one condition (the resting heartbeat), that was changed so we could compare different situations. That change made the activity more than a simple observation; it became an experiment.

Use the words *variable* and *experiment* in the discussion. It is not important that the children build their vocabulary with these words, but they can begin to think about comparing and recording observations, controlling variables to enable comparison, and drawing conclusions from data.

Young children are fascinated with the sound of their own hearts. In this activity pairs of early elementary students investigate that intriguing sound and explore the effect of exercise on heart rate. In this experiment they will gather data, make comparisons, and report their results.

Begin by letting each student hold, listen with, and explore with a stethoscope. Caution the children not to yell into, bang, or squeeze the diaphragm of the scope. Stethoscopes magnify sounds and such actions could hurt or injure the wearer's ears. Students can practice wearing the stethoscopes (the hose from the diaphragm goes to the right ear) and examine the classroom, listening for sounds in usual and unusual places (clocks, windows, walls). The user should clean the earpiece with an alcohol pad before another uses the scope.

The heart makes a double beat that sounds like "lub-dub." Tap the sound on the underside of a table while the children listen with their scopes. Each "lub-dub" counts as a single heartbeat. The students can practice counting the tabletop heartbeats, starting with three or four taps and working up to 15.

Experimenting and Recording

Now it is time to locate and listen to human heartbeats. First, the students listen to each other's hearts. Allow enough time to be sure everyone can hear and identify the beat. The students will measure heart rates for a 15-second interval. Let them practice counting the heartbeats for a timed 15-second interval, then let them "officially" count the number of heartbeats and record the beats. Students then switch roles and repeat. Ask each pair to report their findings on their recording sheet. These numbers provide the data for measuring a "resting" heart beat.

Introducing the Variable

What makes our hearts beat fast? How can we make our hearts beat faster? To determine if exercise changes the rates just measured, one student exercises (runs in place or does jumping jacks) for one minute. The partner then counts the heart rate for 15 seconds and records the result. Give the "start" signal and warn the listeners to get ready with their stethoscopes. When the minute is up, give the "count" signal and the students measure heartbeats for 15 seconds. Have the counter record the heart rate and then let the students switch roles.

Comparing Results

Upon completion of the exercise, let each pair report its results on a data table, drawn on the blackboard with columns for resting and active heart rates.

You will need:

- Stethoscopes, one for each student pair
- Cotton pads and alcohol for cleaning the earpieces
- A recording sheet for each student pair with columns for the resting and active heart rates.

This activity is adapted from the SAVI/SELPH activity "Howdy Heart," one of five activities in the Scientific Reasoning Module developed by the Center for Multisensory Learning, Lawrence Hall of Science, University of California, Berkeley CA 94720. (510) 642-8941.

The Pendulum

An Activity for Older Students

This activity combines a basic physics demonstration with algebraic concepts.

While this experiment does not arise from an everyday problem, ask the students to think of other ways pendulums are used—perhaps a tire swing, a wrecking ball, or a circus trapeze. How would the experiment's results influence the design of those pendulums?

This activity is designed to ensure active participation by all the students. Switch partners to let each person swing, count, and report.

Allow the groups time to discuss such questions as the role of string lengths, how far back to pull the washer, and cutting the additional string. Differences that emerge during the reporting period can be used as discussion points about data collection (How accurate must data be to assure usable results? If we count the swings differently, can we compare the counts?) and the collaborative nature of scientific investigation.

Assessment is built into this activity through teacher questions and student discussions. Predictions and conjectures challenge students to consider additional possibilities or aspects of a situation while analyzing given information and reconsidering its implications.

This activity is adapted from *Facilitating Systemic Change in Science and Mathematics Education: A Toolkit for Professional Developers*, a publication of the Regional Educational Laboratories, available from NEIRL, 300 Brickstone Square, Suite 950, Andover, MA 01810. Thanks to Diane McGowan, mathematics instructor at James Bowie High School and David Molina, Department of Curriculum and Instruction, the University of for their recommendations in ng this activity.

Give each pair of students a washer and a length of string (make sure the strings vary in length) and have them tie the washer to the string, knotting the string at the end. Let them practice counting pendulum swings. One student holds the string by the knot and swings the pendulum while the other student counts the swings. One swing is counted each time the pendulum crosses the center front of the swinger's body. How many swings would occur in 20 seconds? Time a 20-second interval and let the students count the swings. Allow the students to switch roles and do the count again. If the counts are substantially different, a third trial should be made to verify the count.

Have students form groups of four (2 pairs). Ask them to measure the string lengths from the knots to center of the washers and record that number. They will tape the pendulums to the number line on the wall, matching the number of swings to the number on the line. The knot should be taped exactly on the line. The washers on the varying lengths of string will produce a pronounced curve under the number line. What does that curve show us? Are there other ways of presenting the relationship between the length of string and the number of pendulum swings?

Draw a two-column table on the board and ask each group of four to report the recorded string length and swing count of its two pendulums. Compare and discuss the results of the pendulum swings. A graph can provide another picture of the relation between the two variables.

You will need:

- Three identical metal washers for each pair of students
- A metric ruler for each pair of students
- Cotton string cut in varying lengths—One length for each student pair (Variations in string length make this activity more effective)
- Additional string
- Scissors
- A number line marked from 10 to 30 attached to the classroom wall

Distribute graph paper to each group so they can plot the class data displayed on the board.

What happens if we double the string length (2x) or cut it in half (0.5x)? What shape will those lengths produce on the number line? How will they plot on a graph? Distribute two more washers to each pair and have the students cut 2x and 0.5x length strings. Tie and knot those pendulums and time another series of 20-second counts with both new lengths. Let the groups tape the new pendulums to the number line. Are the students' predictions correct? Are there variations in the curve? How important is it to cut the 2x and 0.5x lengths exactly? Now that we've seen a 2x length, what would a 3x length produce?

What other variables affect pendulum behavior? Would a heavier washer give the same number of swings in 20 seconds? What if the washer is initially dropped from a higher or lower point? How long would the pendulum continue to swing on its own? Test these questions as time permits.

Science As Inquiry: Middle Grades and High School

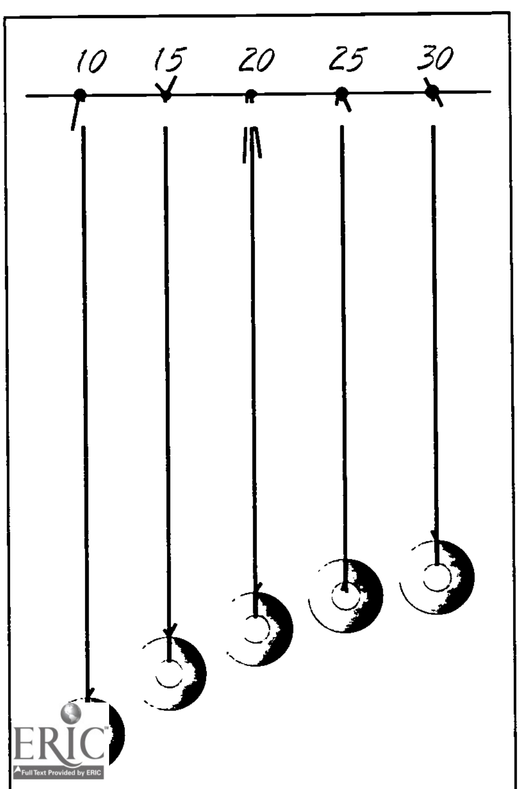
Content Standard for Grades 5–8: Science as Inquiry

Students in grades 5–8 should be provided opportunities to do science in the complete sense. They should have some experiences where they begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results.

At grades 5–8, students can begin to recognize the relationship between explanation and evidence—that background knowledge and theories guide the design of investigations, the types of observations, and the interpretations of data. In turn, the experiments and investigations students conduct become experiences that shape and modify their background knowledge.

Teachers of science for middle school students should note one very important research finding. Students tend to center on evidence that confirms their current beliefs and concepts (personal explanations) and ignore, or fail to perceive, evidence that varies from their current conception. It may be important for science teachers to challenge current beliefs and concepts and provide scientific explanations as alternatives.

Oral or written reports that present the results of the inquiry should be a frequent occurrence in science programs during the middle years. To help focus student thinking, their discussions should center on such questions as "How should we organize the data to present the clearest answer to our question?" or "How should we organize the evidence to present the strongest explanation?" An important element of doing inquiries is the language and practices evident in the classroom. Students need opportunities to communicate scientific explanations and ideas or otherwise use the knowledge and language of science.

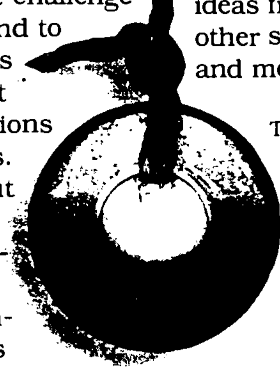


Content Standard for Grades 9–12: Science as Inquiry

In grades 9–12, students should develop a greater sophistication in their abilities and understandings of scientific inquiry. The challenge to teachers of science and to curriculum developers is identifying contexts that make science investigations meaningful for students. Student questions about current scientific topics are one source of meaningful investigations. Actual science and technology-related problems provide another source of investigations. Finally, teachers of science should not overlook the fact that some experiences that begin with little relevance for students can develop meaning through active involvement, exposure, skill, and understanding.

Public discussions of the students' proposed explanations, and peer review of investigations replicate an important aspect of science. Talking with peers about their experiences with science helps students develop meaning and understanding. Their conversations clarify the concepts and processes of science; the conversations help them make sense of science content and methods.

Science teachers should engage students in conversations that focus on questions, such as "How do we know?" "How certain are you of those results?" "Is there a better way to do the investigation?" Questions like these make it possible for students to analyze data, develop a richer knowledge base, reason using science concepts, make connections between evidence and explanations, and recognize alternative explanations. Ideas should be examined and discussed in class so that other students can benefit from the feedback. Teachers of science can use the ideas of students in their class, they may use ideas from other classes, and they may use ideas from texts, databases, or other sources, but scientific ideas and methods should be discussed.

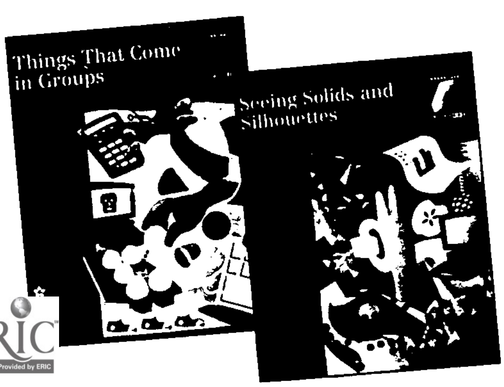


Resources and Opportunities

Investigations in Number, Data, and Space

Try to envision a small group of third graders working around a table with several manipulative materials, talking about whether to use multiplication or division to solve a problem. The students might be working from a new program entitled *Investigations in Number, Data, and Space* offered by Dale Seymour Publishers. This inquiry-based mathematics curriculum, currently available for grades 3 and 4, presents activity books with background and preparation information, lesson plans, reproducible teaching materials, teacher notes, and an assessment plan. Students work together, using concrete materials and technological tools, talking, writing, and drawing about math, finding multiple approaches to problems, and inventing their own strategies. Several of the books include activities for use with Geo-Logo software, which is included.

At present, *Investigations in Number, Data, and Space* provides 21 separate books, 10 for grade 3 and 11 for grade 4. They may be purchased individually; most are $23 each. *Investigations* was developed at TERC (formerly Technical Education Research Center) in Cambridge, Massachusetts. For more information write
Dale Seymour Publications
PO Box 10888
Palo Alto, CA 94303
or call
1-800-872-1100.



Mathematics Learning Forums

The Bank Street College of Education is sponsoring a series of on-line seminars for elementary and middle school mathematics teachers. Participants from around the nation will discuss specific aspects of mathematics

teaching. During the fall 1995 or spring 1996 semesters, 18 forums will be offered. Forum themes include:

- Assessing Students through Focused Observations (K–4)
- Investigating Patterns in Mathematics (5–8)
- Teaching Probability (5–8)
- Engaged Learning: When Does a Child Really Learn? (K–4)

An on-line facilitator will host the sessions and teachers will view videotapes of students and teachers in many school settings. Graduate credits and inservice credits are available for additional registration fees.

For a registration form and more information phone **(212) 807-4207**; email **cct@edc.org**
or visit the Web Site at
http://www.edc.org/CCT/mlf/MLF.html

Pathways to School Improvement

The North Central Regional Educational Laboratory (NCREL) in Oak Brook, Illinois, has prepared *Pathways to School Improvement*, an examination of reform in mathematics and science education. The *Pathways* address on the World Wide Web **(http://cedar.cic.net/ncrel/sdrs/pathways.htm)** outlines a variety of selections that include assessment, leadership, governance, and school to work. The mathematics and science sections examine such issues as providing authentic learning experiences in science, ensuring equity in science and mathematics instruction, and the significance of the NCTM *Standards*. The site provides thoughtful discussions that support educational reform for mathematics and science education.

The Journey Inside: The Computer

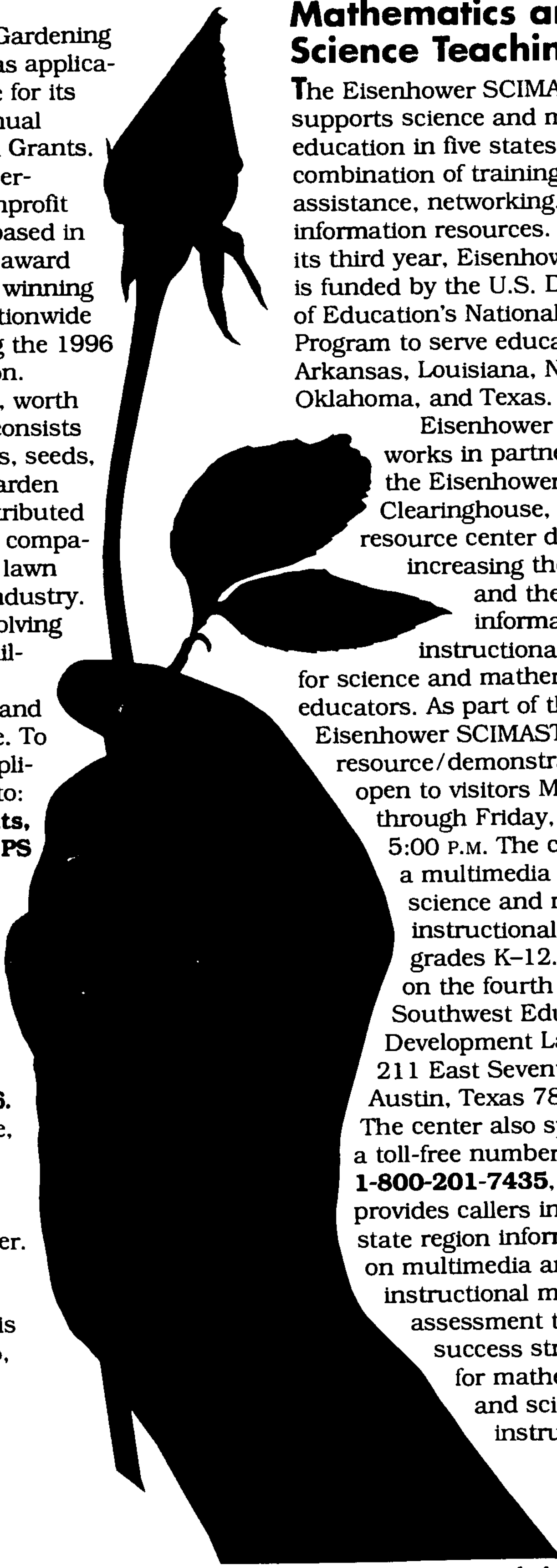
Nothing can replace hands-on experience for learning computer skills. As an introductory segment to learning about the internal workings of the machine and the history of its development, however, this free instructional kit from Intel Corp could be helpful. The

kit (pictured at left) includes instructional materials and an introductory video, but best of all is the Chip Kit: a collection of processor chips, a packaged microprocessor, and a silicon wafer. These artifacts can be passed around and closely examined without fear of breaking or contaminating them. The kit is available to teachers of mathematics, science, or computers in grades 5 through 9. To obtain an order form call
1-800-346-3029 ext. 143.

Youth Garden Grants

The National Gardening Association has applications available for its thirteenth annual Youth Garden Grants. NGA, a member-supported nonprofit organization based in Vermont, will award 300 grants to winning applicants nationwide for use during the 1996 growing season.

Each grant, worth about $500, consists of quality tools, seeds, plants, and garden products contributed by 28 leading companies from the lawn and garden industry. Programs involving at least 15 children between the ages of 3 and 18 are eligible. To receive an application, write to: **Garden Grants, Department PS National Gardening Association, 180 Flynn Avenue, Burlington VT 05401** or call: **1-800-538-7476.** Include name, school or organization, address, and phone number. Deadline for completed applications is November 15, 1995.



Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

The Eisenhower SCIMAST project supports science and mathematics education in five states with a combination of training, technical assistance, networking, and information resources. Completing its third year, Eisenhower SCIMAST is funded by the U.S. Department of Education's National Eisenhower Program to serve educators in Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.

Eisenhower SCIMAST works in partnership with the Eisenhower National Clearinghouse, a national resource center dedicated to increasing the availability and the quality of information about instructional resources for science and mathematics educators. As part of that effort, Eisenhower SCIMAST supports resource/demonstration center open to visitors Monday through Friday, 8:00 A.M. to 5:00 P.M. The center houses a multimedia collection of science and mathematics instructional materials for grades K–12. It is located on the fourth floor of the Southwest Educational Development Laboratory, 211 East Seventh Street, Austin, Texas 78701. The center also sponsors a toll-free number, **1-800-201-7435**, that provides callers in the five-state region information on multimedia and print instructional materials, assessment tools, and success strategies for mathematics and science instruction.

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

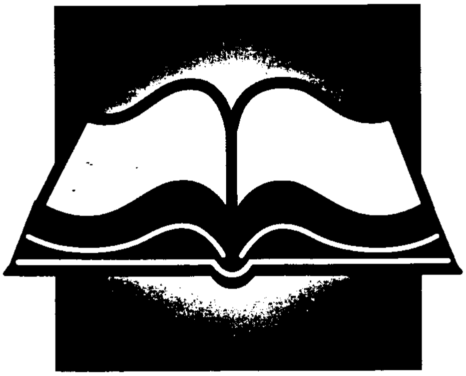
Eisenhower SCIMAST Staff:

Wesley A. Hoover, director
Glenda Clark, senior training associate
Marilyn Fowler, senior training associate
Marilyn Irving, senior training associate
Gary Ketterling, senior training associate
Jackie Palmer, senior training associate
Barbara Salyer, senior training associate
Maria Torres, senior training associate
Jack Lumbley, evaluation associate
Kathy Schmidt, evaluation associate
Mary Jo Powell, technical writing associate
Sharon Adams, information specialist
Lori Snider, administrative assistant
Veronica Lopez, administrative secretary
Dawn McArdle, administrative secretary

Classroom Compass is a publication of the Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching (SCIMAST) project, sponsored by the U. S. Department of Education under grant number R168R20003-94. The content herein does not necessarily reflect the views of the department or any other agency of the U.S. government. *Classroom Compass* is distributed free of charge to public and private schools in Arkansas, Louisiana, New Mexico, Oklahoma, and Texas to support improved teaching of mathematics and science. The Eisenhower SCIMAST project is located in the Southwest Educational Development Laboratory (SEDL) at 211 East Seventh Street, Austin, Texas 78701; (512) 476-6861/800-201-7435. Associate editors: Sharon Adams and Mary Jo Powell with assistance from the Editorial Committee, Glenda Clark and Marilyn Irving. Thanks to the rest of the Eisenhower SCIMAST staff for their continued help with planning, reading, discussing, and praising. Publication design: Jane Thurmond.

Equity in Science and Mathematics Education

A READING LIST



Equity in the Reform of Mathematics and Science Education: A Look at Issues and Solutions
by Mary Jo Powell
Available from:
Southwest Educational Development Laboratory
211 East Seventh Street
Austin, Texas 78701
Full report $21,
Executive Summary $2

A review of the literature concerning equity in mathematics and science education, this book is designed as a reference tool for those working to change policy and practices. A 30-page executive summary is available as well as the complete 185-page document.

Equity Materials in Mathematics, Science, and Technology: A Resource Guide
by Marylin A. Hulme
Available from:
Mid-Atlantic Eisenhower Consortium for Mathematics and Science Education,
Research for Better Schools
444 North Third Street
Philadelphia, PA 19123
Free

A 35-page annotated bibliography (2nd edition: August 1994) of print and nonprint materials focused on equity in math and science. Also ...nts resources for career ...mation.

Lifting the Barriers: 600 Strategies that REALLY WORK to Increase Girls' Participation in Science, Mathematics, and Computers
by Jo Sanders
Available from:
Jo Sanders
P.O. Box 483
Port Washington, NY 11050
$13.95 + 15% shipping & handling

This collection of suggestions and tips includes both simple strategies ("Use a sign-up sheet that alternates girls and boys for computer time") and more complicated endeavors ("Set up a summer mentorship program for girls in your school"). Topics include suggestions for fund-raising, field trips, extracurricular activities, curriculum ideas, and participation in contests and competitions.

"Meeting the Challenges of Diversity and Relevance"
by Margaret Schwan Smith and Edward A. Silver
Mathematics Teaching in the Middle School
September-October 1995,
Pages 442–448.

This journal article discusses mathematics instruction, relating students' experiences and interests to classroom activities. The journal is published by the National Council of Teachers of Mathematics (NCTM).

Science Equals Success
by Catherine R. Conwell
Available from Women's Education Equity Act Publishing Center
55 Chapel Street, Suite 200
Newton, MA 02158-1060
$16.00

This collection of hands-on, discovery-oriented science activities puts special emphasis on problem-solving, cooperative learning, spatial skills, and career awareness.

The SAVI/SELPH Program (Scientific Activities for the Visually Impaired/Science Enrichment for Learners with Physical Handicaps)
Lawrence Hall of Science
University of California
Berkeley, CA 94720
Telephone (510) 642-1016

The SAVI/SELPH kits, print materials, and video resources from the Center for Multisensory Learning, while originally designed for disabled students, have been found to have "significant application in regular upper-elementary classrooms" (SAVI/SELPH brochure). The reasonably priced packets and videos include activities that focus on communication, environmental energy, kitchen interactions, magnetism and electricity, mixtures and solutions, scientific reasoning, structures of life, and measurement. Materials kits that provide the "stuff" of scientific investigation (basins, water jugs, washers, string, etc.) are available for purchase or rent. Call for a catalog with specific price listings.

Science Teams: Elementary Teachers and Students Discover Environmental Science Through Cooperative Learning
by Aleta You Mastny, Sami Kahn, and Sharon J. Sherman
Available from:
Consortium for Educational Equity
Rutgers University
Bldg. 4090, Livingston Campus
New Brunswick, NJ 08903
$150.00

A teacher's manual accompanies a videotape presenting ideas for using cooperative learning in the elementary science classroom with a particular focus on encouraging girls and minority students.

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

Classroom Compass

Spring 1996 • Volume 2, Number 2

HIGHLIGHTS

Assessment: A Window to Learning

Betty Culver never felt comfortable with traditional report cards for her students. In fact, she was not satisfied with any form of impersonal reporting. Describing the complexity of the children's learning throughout the year was difficult. Even parent conferences, which did provide face-to-face explanations of the students' achievements, could not adequately describe their growth and development. How could one gather all the details from the past six weeks and communicate them in one short session to a listening parent? Betty's solution was to capture on-going classroom work and teacher-student interviews on video. She showed clips to the parents as an introduction to their conference discussion. The videos helped her effectively communicate student progress and analyze her own instruction. Assessment became a tool of learning, not a weapon of control.

Defining Our Goals

What should instruction accomplish? Should students be memorizing multiplication facts or solving problems? Or both? Should they be conducting inquiries or studying codified scientific understanding? Or both? The answers to such questions should be the basis for assessment strategies. When expectations for a core of knowledge, skills, and practices are defined, teachers and students can identify what is required for success. Rigorous standards, which articulate expectations or benchmarks for students at various grade levels, can provide a foundation for teachers, schools, and communities to build an assessment structure.

continued on page 2

Assessment, *continued*

Assessment results can be guideposts that help both teacher and student identify what has been learned and what areas need further work. They can be used as part of a cycle that includes instruction and assessment, then evaluation and redesign of instruction. Such assessments are an integral part of the teaching day, not a report that appears every six weeks. As much a reflection of the instruction's success as of the student's progress, assessment can help teachers redirect their efforts to match students' strengths or weaknesses. Assessment should also help students think about their own learning.

Fitting Assessment with Instruction

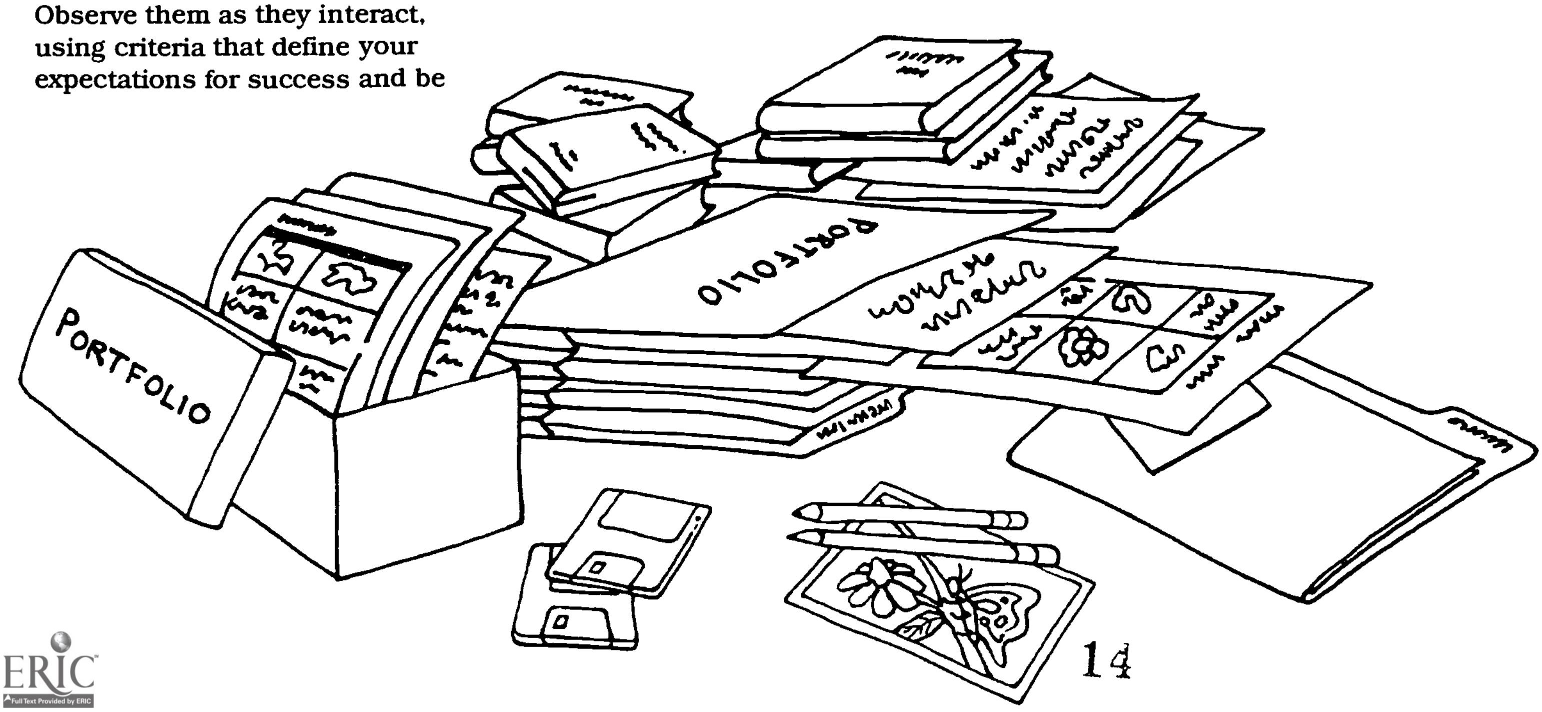
To be sure assessment supports learning, match it with classroom experience. While textbook-based tests measure what the textbook has presented, they will not provide information about students' contributions to a lively class discussion. If students spend their time working in groups, they should be assessed in a similar setting. Observe them as they interact, using criteria that define your expectations for success and be sure they know your expectations before assessment occurs. If they use calculators to solve problems, give them the same tools to complete their assessment.

If the goal of instruction is to assist all students in developing their understanding of mathematics and science, use assessment to help them expand their understanding. While a single assessment indicates understanding at a particular moment, a collection of student work and the teacher's perceptions provides a reflection of the fluid, dynamic nature of learning. Assessment that occurs as teachers listen, observe, interact, and reflect provides a picture of student development over time.

Tools for Record-keeping

Each day students provide evidence of their understanding in many ways—through explanations, discussions, projects, and questions. This evidence of student learning can be lost if there is no conscious effort to keep track. Traditional report card grades and paper-and-pencil tests reflect only a part of the classroom experience; teachers need a variety of record-keeping and reporting strategies to capture other evidence of growth in understanding. These can include videos as well as checklists, rubrics, student portfolios, and project evaluations—tools that can convey the complexity of student learning.

Teachers are researchers in their classrooms. They are engaged in observing students who are engaged in learning. Walking around the classroom with a clipboard and an observation sheet can be an effective way to keep track of student progress. Some teachers have found that personal digital assistants (PDAs) are invaluable portable aids to data collection. These hand-held electronic record-keepers can be programmed with learner profiles and defined characteristics the teacher will be looking for. The information can later be downloaded to a computer. Another tool—the camera—can be used to take photographs that record activities and projects providing excellent reminders of events, student participation, and products.



Putting Numbers on Performance

Single-answer questions are easy to score. Part of the power of standardized, single-answer tests is the solid, quantifiable numbers they produce. But how does a teacher quantify an open-ended class discussion? What can be reported about the processes used in a science investigation? Teachers need ways to organize and report what occurs in the classroom. One way to do this is through the use of rubrics. Rubrics are scoring guides that assign numerical values to achievement outcomes.

Many rubrics include examples that illustrate and differentiate between the different categories. For instance, one of the rubrics below addresses observation—an essential skill in scientific investigation. The example provides a continuum of designations of observational skill: Novice ("Sees only obvious things"), Proficient ("Can quantify observations"), or Advanced ("Uses patterns and relationships to focus further observations"). Content knowledge is categorized in a similar way in the Food for Animals rubric.

Getting Others' Views

Even with the aid of good instruments and tools, a teacher may want to involve others in the assessment process. Expanding the audience for student performance helps guard against personal biases and adds the value of additional perceptions to the assessment process. A team of teachers can cooperatively grade a collection of portfolios or projects. Groups of teachers who regularly discuss assessment practices and issues will uncover alternative views of students' achievements. Teams from within the school or the community can examine collections of students' work or be the audience for student presentations. Students can contribute by suggesting evaluation criteria and voicing their views of what constitutes acceptable and quality work.

Assessment is an essential part of the teaching process; some say it actually drives instruction. If this is true, then introducing alternative ways of assessing students will result in different ways of teaching. Instruction that helps students perform confidently on a performance test is very different from instruction that prepares students for a paper-and-pencil test. The resultant learning will reflect those differences.

FOOD FOR ANIMALS

N	• Anything an animal takes in is food.
N+	• Shows some ideas from Novice level and some from Proficient level.
P	• Animals need food, water, and air to live. • Animals get food from eating plants or other animals. • Animals get both nutrients and energy from food.
	• Shows some ideas from Proficient level, and some from Advanced level.
A	• Unlike plants, animals take in food and break it into small particles in their guts. • Some food energy is stored inside animals, and some is released as heat when animals use the food to grow and function.

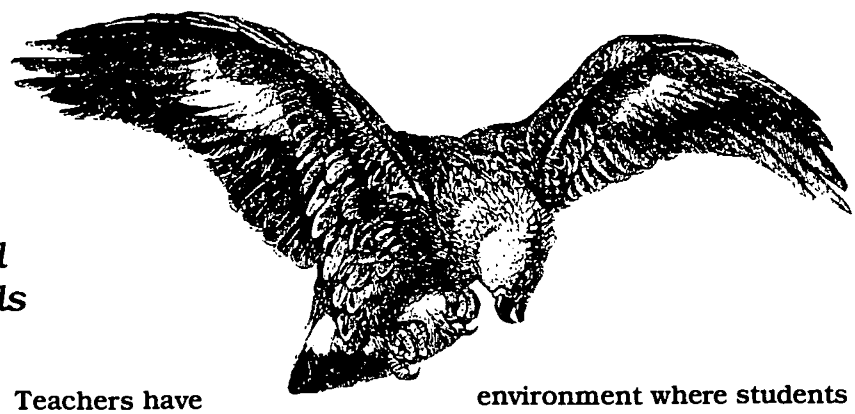
OBSERVING AND MEASURING

N	• Sees only obvious things Notices few details or changes; poor discrimination ability • Doesn't use all senses
N+	• Makes somewhat focused and active observations, but their quality, depth, breadth, and accuracy is inconsistent
P	• Uses all senses to notice details, patterns, similarities, and differences • Can quantify observations using appropriate measurements
	• Follows a regular program of observation and measurement • Makes objective and accurate observations and measurements consistently
A	• Judges how frequent and accurate observations and measurements need to be for an experiment, and makes them accordingly • Uses discerned patterns and relationships to focus further observations

See *Classroom Assessment: A List of Readings* on page 10

Developing Self-Directed Learners

an excerpt from the *National Science Education Standards*



Students need the opportunity to evaluate and reflect on their own scientific understanding and ability. Before students can do this, they need to understand the goals for learning science. The ability to self-assess understanding is an essential tool for self-directed learning. Through self-reflection, students clarify ideas of what they are supposed to learn. They begin to internalize the expectation that they can learn science. Developing self-assessment skills is an ongoing process throughout a student's school career, becoming increasingly more sophisticated and self-initiated as a student progresses.

Conversations among a teacher and students about assessment tasks and the teachers' evaluation of performance provide students with necessary information to assess their own work. In concert with opportunities to apply it to individual work and to the work of peers, that information contributes to the development of students' self-assessment skills. By developing these skills, students become able to take responsibility for their own learning.

Teachers have communicated their assessment practices, their standards for performance, and criteria for evaluation to students when students are able to

- Select a piece of their own work to provide evidence of understanding of a scientific concept, principle, or law—or their ability to conduct scientific inquiry.
- Explain orally, in writing, or through illustration how a work sample provides evidence of understanding.
- Critique a sample of their own work using the teacher's standards and criteria for quality.
- Critique the work of other students in constructive ways.

Involving students in the assessment process increases the responsibilities of the teacher. Teachers of science are the representatives of the scientific community in their classrooms; they represent a culture and a way of thinking that might be quite unfamiliar to students. As representatives, teachers are expected to model reflection, fostering a learning environment where students review each others' work, offer suggestions, and challenge mistakes in investigative processes, faulty reasoning, or poorly supported conclusions.

A teacher's formal and informal evaluations of student work should exemplify scientific practice in making judgments. The standards for judging the significance, soundness, and creativity of work in professional scientific work are complex, but they are not arbitrary. In the work of classroom learning and investigation, teachers represent the standards of practice of the scientific community. When teachers treat students as serious learners and serve as coaches rather than judges, students come to understand and apply standards of good scientific practice.

A WRITTEN ASSESSMENT FOR ELEMENTARY STUDENTS

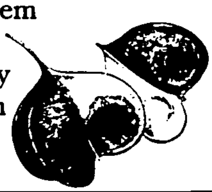
Environmental Impact Statements

Students predict the effects of a cleanup effort on their outdoor study site

This Environmental Impact Statement assignment is part of Who Eats What?—a 4-week unit on the ecology of food webs for upper elementary students. During the unit, students work to determine the food web of a chosen outdoor study site—possibly the schoolyard or a nearby park. The unit includes classroom and field-based studies, games, presentations, and background readings that support reflection, discussion, and exploration.

Assessment data is collected throughout **Who Eats What?** Students contribute to journals or e-mail, save materials for portfolios, and complete self-evaluations and group evaluations. They also complete two erformance events: the development of an interpretive outdoor study station for the field study site and an exhibition about "Who Eats What?" for an invited audience. Students who have completed several weeks' work on the unit would be ready for the Environmental Impact Statement assignment.

In the introduction to this activity, let the class members discuss their ideas of what constitutes good work. The list at right gives an idea of possible criteria that might be suggested. You may want to assign a point system to help your analysis. For example, correctly tracing the food chain might get a higher score than mentioning an organism that would die from the cleanup. Let the rubric reflect what you and your class think is important.



The students can discuss ideas for the statement in pairs, then individually write an Environmental Impact Statement addressed to the landowner. After a class discussion about the statements, the students can evaluate their work and choose samples for a portfolio.

By the end of this activity, students should have demonstrated:

- Their understanding of how changes in a landscape could ripple through a food web.
- Their understanding of the importance of considering the food web of a piece of land before altering it.

The Scenario

A new business called the Clean Up Crew Two has made a special offer to the owner of your study site. After its parent company, the Clean Up Crew, picks up any trash on the site, Clean Up Crew Two will clear away all the dead leaves, branches, logs, and all other dead material on the ground. Clean Up Crew Two will also remove dead branches from living plants, and dead plants that are still standing. They say that their work will make the site a neater, cleaner, and safer place for people to enjoy. Their first visit will be free, then the landowner will pay a discount price for a cleanup every six months.

Student Challenge:
Write an Environmental Impact Statement in the form of a letter to the study site landowners. Say what you predict would happen to the things that live on the site if the owners accept the cleanup offer. Give examples of how each thing affected could cause other changes in the food web. You may use food chains, food webs, and resource books to help figure out how Clean Up Crew Two's work could affect the site.

Environmental Impact Statement:
Essential Points

Content

- Mentions organisms that would die or lose their food source
- Mentions organisms that could increase
- Uses food chain vocabulary

Scope

- Describes how one change could affect more than one food chain in a food web
- Correctly traces a food chain through at least two steps

Communication

- Overall, presents a clear, detailed, and convincing argument for why to accept or not accept the cleanup offer

SCORED DISCUSSIONS FOR UPPER LEVEL STUDENTS

Thinking Aloud About Mathematics

This assessment actively involves an entire mathematics class in a problem-solving discussion. Eilene Leach explained this method of challenging her Colorado high school students in "An Alternative Form of Evaluation" in the November 1992 issue of The Mathematics Teacher.

Several days a week Eilene Leach begins class with the following scenario: a challenging homework problem is presented to a group of four students who sit in front of their classmates. The group is given five minutes to discuss and solve the problem while the rest of the class observes.

"When I first tried scored discussion, I was afraid the students would hate it. I was wrong. Those students in front of the class were trying their best, since they were working in front of their peers. The students in the audience listened intently. I learned more about how students reasoned than I had by watching them in cooperative groups....[After the timer bell rang] the audience could contribute to the suggestions.... Sometimes the students in the audience were so excited they could hardly keep quiet until the five-minute timer rang."

Leach has developed a rubric that she uses to score group members as they puzzle through the problem. Problem-solving skills and the successful use of appropriate mathematical strategies are valued, as are indications of skillful group interaction.

"By seeing the scored discussions the students learned how to discuss mathematics....When a group has a particularly difficult time with their problem, I pull my chair into the group and continue the discussion for several more minutes, modeling how to develop a strategy and how to involve all members in the solution process."

This activity provides the students an arena for public discourse about mathematics. It accommodates several NCTM curriculum standards including:

- Learning to reason mathematically
- Learning to communicate mathematically
- Becoming mathematical problem solvers

The discourse sessions give every participant the possibility of success.

The sessions provide an alternative to paper-and-pencil assessments and let students explain their thinking and demonstrate their ideas.

Once or twice a semester, Leach devotes the entire period to scored discussions.

At the beginning of the semester, Leach explains the activity and enlists several students in a "trial run." She emphasizes problem-solving strategies and successful group techniques as well as ways students can lose points through interrupting or monopolizing the discussion. She gives the students copies of the score sheet so they will know expectations for a successful session. An added bonus: if the students solve the problem, it is not on that night's homework.

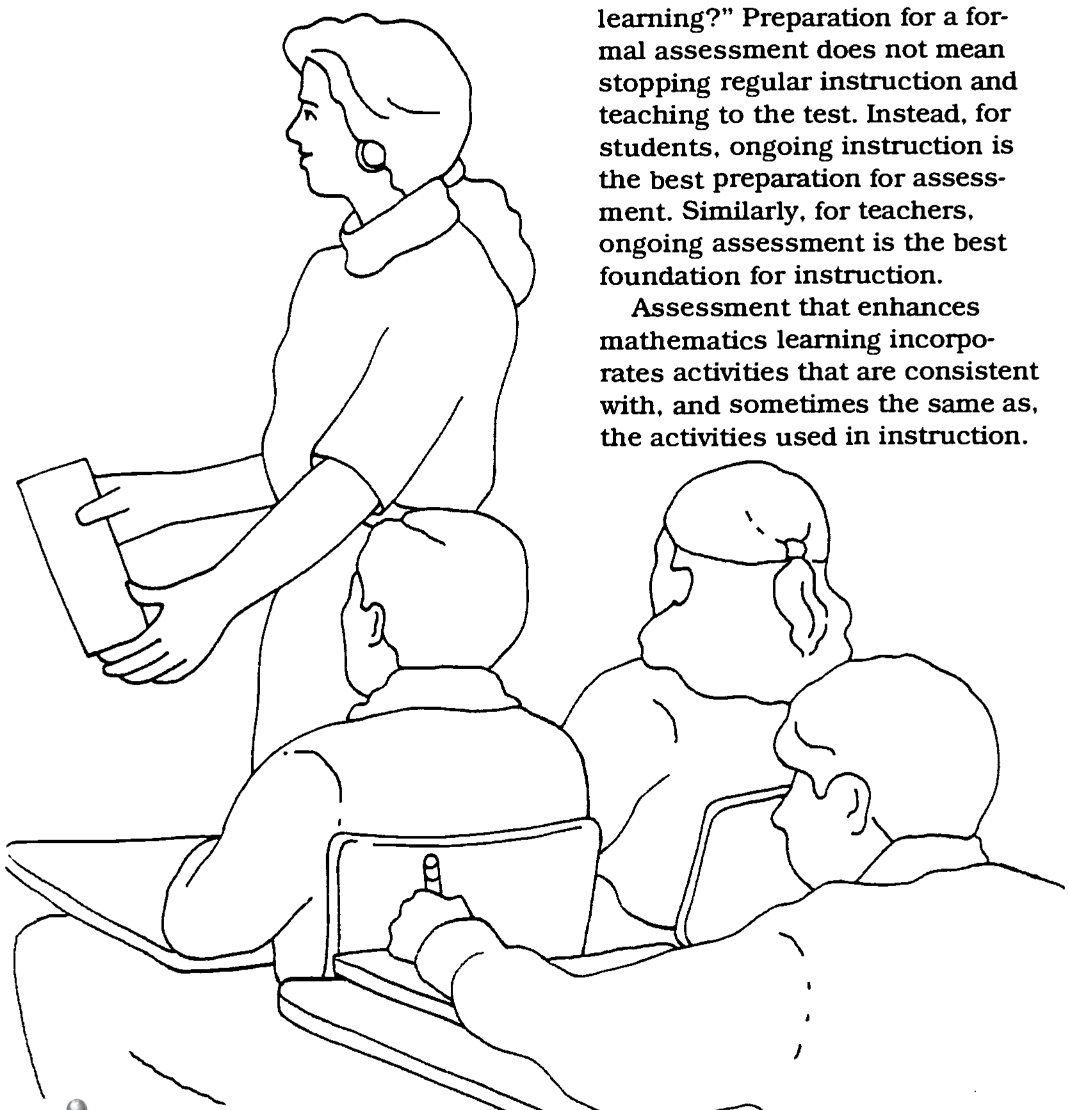
Discussion Scoring Guide

Positive Points	
• Determining a possible strategy to use	+3 points
• Successfully communicating a strategy	+3 points
• Correctly applying a property	+2 points
• Recognizing misused properties or arithmetic errors	+2 points
• Drawing another person into discussion	+2 points
• Asking a clarifying question	+3 points
• Moving the discussion along	+1 point
Negative Points	
• Not paying attention or distracting others	-2 points
• Interrupting	-2 points
• Making an incorrect assumption	-2 points
• Making a personal attack	-3 points

The Learning Standard: Assessment in Mathematics Classrooms

an excerpt from *Assessment Standards for School Mathematics*

Assessment that enhances mathematics learning becomes a routine part of ongoing classroom activity rather than an interruption. Assessment does not simply mark the end of a learning cycle. Rather, it is an integral part of instruction that encourages and supports further learning. Opportunities for informal assessment occur naturally in every lesson. They include listening to students, observing them, and making sense of what they say and do. Especially with very young children, the observation of students' work can reveal qualities of thinking not tapped by written or oral activities. In planning lessons and making instructional decisions, teachers identify opportunities for a variety of assessments. Questions like the following become a regular part of the teacher's planning: "What questions will I ask?" "What will I observe?" "What activities are likely to provide me with information about students' learning?" Preparation for a formal assessment does not mean stopping regular instruction and teaching to the test. Instead, for students, ongoing instruction is the best preparation for assessment. Similarly, for teachers, ongoing assessment is the best foundation for instruction.



Assessment that enhances mathematics learning incorporates activities that are consistent with, and sometimes the same as, the activities used in instruction. For example, if students are learning by communicating their mathematical ideas in writing, their knowledge of mathematics is assessed, in part, by having them write about their mathematical ideas. If they are learning in groups, they may be assessed in groups. If graphing calculators are used in instruction, they are to be available for use in assessment.

Students' classroom work, along with projects and other out-of-class work, is a rich source of assessment data for making inferences about students' learning. Many products of classroom activity are indicators of mathematics learning: oral comments, written papers, journal entries, drawings, computer-generated models, and other means of representing knowledge. Students and teachers use this evidence, along with information from more formal assessment activities, to determine next steps in learning. Evidence of mathematics learning can be found in activities that range from draft work, through work that reflects students' use of feedback and helpful criticism, to a polished end product. Continuous assessment of students' work not only facilitates their learning of mathematics but also enhances their confidence in what they understand and can communicate. Moreover, external assessments support instruction most strongly when classroom work is included. When classroom work, the teacher's judgments, and students' reflections are valued parts of an external assessment, they enhance students' mathematics learning by increasing the fit between instructional goals and assessment.

Resources and Opportunities

A Personal Digital Assistant

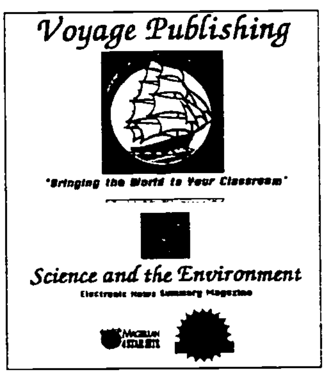
The Newton MessagePad, made by Apple Computer, is an electronic device that converts written notes into typed documents, which can then (with an additional connection kit) be transferred to a Macintosh computer or a PC that uses Windows software. Load these hand-held devices with appropriate software and student assessment profiles can be designed to fit your specifications. This gadget serves as an electronic clipboard that lets the user gather, organize, and interpret data more efficiently than with paper-and-pencil records. For further information about the educator's advantage price, call Apple at 1-800-959-2775. The Newtons cost around $500 with the educator's advantage.

Learner Profile

Sunburst educational software company offers assessment software that can be loaded on the Apple Newton or used with a bar code scanner to provide a mobile data collection tool. The software allows the user to create descriptions of desired student learning on the computer, then transfer the data to the hand-held device. After the data are collected (at the end of the day, at the end of the week), transfer the observations back to the computer for analysis, grouping, and report generation. A 1.4 MB disk for Macintosh or Windows is priced at $99. Call Sunburst 1-800-321-7511.

Eco-Inquiry

A hefty volume of 392 pages, *Eco-Inquiry* provides three ecology modules for upper elementary or middle grades. The four-to-seven week modules examine food webs, decomposition, and nutrient cycling and include suggestions for hands-on investigations, discussions, games, writing assignments, and presentations. Assessment is encouraged throughout the modules with ideas for journal topics, collection of portfolio materials, suggestions for written and performance activities, and student self-evaluations. *Eco-Inquiry* by Kathleen Hogan. Dubuque, Iowa: Kendall-Hunt Publishing Company. 1994. $36.95

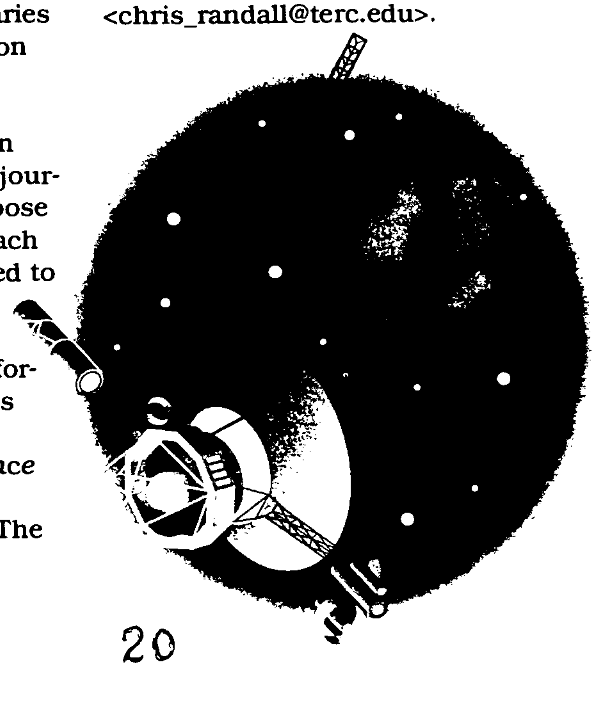


Voyage Web Site

This bimonthly internet magazine provides summaries of news stories on environmental issues. Editors review more than 500 magazines, journals, and newspapers and choose 80 articles to summarize in each issue. Students are encouraged to copy the summaries and use them for classroom research sources. Full bibliographic information on the original sources (an eclectic list that includes *ZooNooz*, *The Christian Science Monitor*, *Newsweek*, and *The Jerusalem Post*) is provided. The Web address is: <http://www.voyagepub.com/publish>.

Mars Modules

The TERC corporation (formerly Technical Education Research Center), located in Cambridge, Massachusetts, continues to develop exciting products and programs for mathematics and science educators. In anticipation of upcoming orbiter and lander missions, TERC, in collaboration with NASA, is developing hands-on, discovery-oriented investigations focusing on the planet Mars. Developers are looking for middle-school teachers to field test pilot materials during the 1996-1997 school year. Units currently available are Planetary Exploration, Volcanoes, and Valley Formation. The activities enable students to confront preconceptions, refine questions for investigation, construct meaning from images and data, develop hypotheses, collect evidence in support of hypotheses, and synthesize understanding. The modules vary in length from two to three weeks and include materials for teachers and students as well as assessment tools. The pilot activities have no technology requirements. For more information, call (617)-547-0430 or e-mail Chris Randall <chris_randall@terc.edu>.



Professional Development Awards

Congratulations to recipients of Eisenhower SCIMAST Professional Development Awards. Over 100 schools, university programs, nonprofit organizations, and community groups applied for the five-year awards offered to educators in SCIMAST's five-state region. The successful proposals emerged from a series of reviews including several SCIMAST staff reviews, scrutiny by a 10-member expert panel and final approval by a 15-member Consortium Advisory Board. The programs will receive up to $20,000 per year to carry out their professional development activities in science or mathematics education. The successful recipients are

Albuquerque Public Schools
Annalee Maestas and
Dolores Varela-Phillips,
Project Co-Directors
Albuquerque, New Mexico

College of Santa Fe
Manon Charbonneau,
Project Director
Santa Fe, New Mexico

Deer Park Educational Foundation
Nancy Hodges, Project Director
Deer Park, Texas

Ector County ISD
Rita Latimer, Project Director
Odessa, Texas

Konawa Public Schools
C.J. Vires, Project Director
Konawa, Oklahoma

New Mexico State University
Elaine Hampton, Project Director
Las Cruces, New Mexico

Northeast Louisiana University
Rhonda Adams, Project Director
Monroe, Louisiana

University of Texas Marine Science Institute
Rick Tinnin, Project Director
Port Aransas, Texas

University of Texas Science and Technology Center
[illegible]n White, Project Director
[illegible]tin, Texas

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

The Eisenhower SCIMAST project supports science and mathematics education in five states with a combination of training, technical assistance, networking, and information resources. Eisenhower SCIMAST is funded by the U.S. Department of Education's National Eisenhower Program to serve educators in Arkansas, Louisiana, New Mexico, Oklahoma, and Texas. Eisenhower SCIMAST works in partnership with the Eisenhower National Clearinghouse, a national resource center dedicated to increasing the availability and the quality of information about instructional resources for science and mathematics educators. As part of that effort, Eisenhower SCIMAST has a resource/demonstration center open to visitors Monday through Friday, 8:00 A.M. to 5:00 P.M. The center houses a multimedia collection of science and mathematics instructional materials for grades K–12. It is located on the fourth floor of the Southwest Educational Development Laboratory, 211 East Seventh Street, Austin, Texas 78701. The center also has a toll-free number, **1-800-201-7435**, that provides callers in the five-state region information on multimedia and print instructional materials, assessment tools, and successful strategies for mathematics and science instruction.

Eisenhower SCIMAST Staff:
Wesley A. Hoover, director
Glenda Clark, senior training associate
Marilyn Irving, senior training associate
Jackie Palmer, senior training associate
Barbara Salyer, senior training associate
Maria Torres, senior training associate
Jack Lumbley, evaluation associate
Kathy Schmidt, evaluation associate
Mary Jo Powell, technical writing associate
Sharon Adams, information associate
Lori Snider, administrative assistant
Veronica Lopez, administrative secretary
Dawn McArdle, administrative secretary

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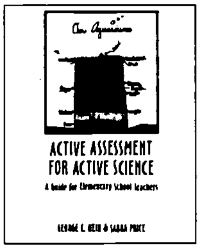
Classroom Assessment

Hein, George E., and Sabra Price
Active Assessment for Active Science: A Guide for Elementary School Teachers
Portsmouth, NH: Heinemann, 1994

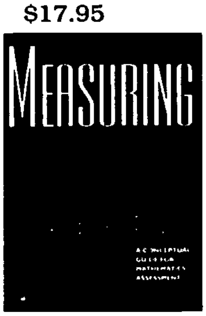
Heinemann Publishing
361 Hanover Street
Portsmouth, NH 03801-3912
$10.00



Hein and Price present ideas for assessment that accompanies active learning. With a focus on the elementary science classroom, the authors devote much of the book to practical suggestions for managing assessment of active learning. They also discuss ways to interpret and score children's science work. Illustrations and explanations of assessment tools include questionnaires, drawings, student self-evaluations, folders, notebooks, and embedded products and activities.

Mathematical Science Education Board
Measuring What Counts: A Conceptual Guide for Mathematics Assessment
Washington, DC: National Academy Press

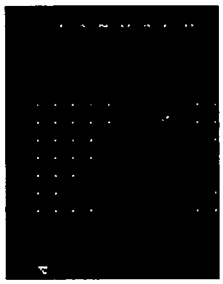
National Academy Press
2101 Constitution Ave. N.W.
Washington, DC 20418
1-800-624-6242
$17.95



Cited as the scholarly base for NCTM's *Assessment Standards*, this report provides a research-based argument for mathematics assessment that not only measures results, but also contributes to the educational process itself. The report focuses on three fundamental principles: the content principle ("Assessment should reflect the mathematics that is most important to learn"), the learning principle ("Assessment should enhance mathematics learning and support good instructional practice"), and the equity principle ("Assessment should support every student's opportunity to learn important mathematics").

National Council of Teachers of Mathematics
Assessment Standards for School Mathematics
Reston, VA: Author, 1993

NCTM, 1900 Association Drive
Reston, VA 22091
1-800-235-7566
$25.00



Published in 1995, the *Assessment Standards* complements the earlier *Curriculum Standards* (1989), and the *Professional Standards* (1991), all written by groups of mathematics educators supported by NCTM. The *Assessment Standards* presents strategies and practices to help teachers assess students in a manner that reflects the reformed mathematics classroom. *Assessment Standards* addresses six major themes: mathematics, learning, equity, openness, inferences, and coherence.

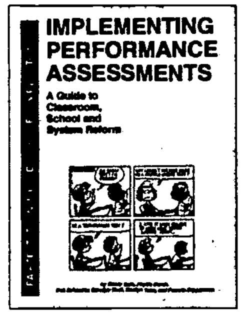
National Research Council
National Science Education Standards
Washington, DC: National Academy Press, 1996

National Academy Press,
2101 Constitution Ave. N.W.
Washington, DC 20418
1-800-624-6242
$16.50

In the recently published *National Science Education Standards*, a chapter on assessment presents five standards that emphasize consistency, probing for student understanding, authenticity, fairness, and sound inference from assessment data. For teachers, the authors suggest using assessment data to plan curricula, improve classroom practice, develop self-directed learners, report student progress, and inquire into their own teaching.

Neill, Monty, et al
Implementing Performance Assessments: A Guide to Classroom, School and System Reform
Cambridge, MA: FairTest, n.d.

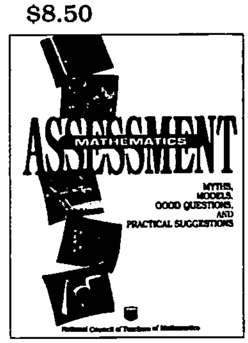
The National Center for Fair and Open Testing
342 Broadway
Cambridge, MA 02139
(617) 864-4810
$6, discounts for multiple copies



The National Center for Fair and Open Testing presents this guide for teachers, administrators, parents, community members, anyone "interested in using performance assessments in their classrooms and school systems." The 56-page booklet argues in support of performance-based testing and suggests ways various players (i.e. teachers, parents, etc.) can work to change traditional assessment practices. It also includes practical suggestions for scoring, developing rubrics, record-keeping, performance exams and projects.

Stenmark, Jean K., ed.
Mathematics Assessment: Myths, Models, Good Questions, and Practical Suggestions
Reston, VA: National Council of Teachers of Mathematics, 1991

NCTM, 1900 Association Drive
Reston, VA 22091
1-800-235-7566
$8.50



This book offers mathematics teachers an introduction to assessment techniques that focus on student thinking. The first segments of the book discuss such myths of teaching and testing as "in the classroom, only the teacher can adequately evaluate a student's progress" or "the purpose of assessment is to determine which students 'have it' and which do not." Later chapters provide suggestions and examples for introducing a variety of assessment methods in K–12 mathematics lessons. One chapter is devoted to mathematics portfolios.

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

Classroom Compass

Summer 1996 • Volume 2, Number 3

HIGHLIGHTS

Design in the Classroom

Students in Ms. Clark's fifth-grade science class are busy. Their desks are clustered in several work areas and a few of the students are sitting on the floor, intently piecing together parts of cereal boxes and wooden ice cream sticks. One student is making a rough sketch on the chalkboard. An assigned problem is defined on a chart:

Grandmother can't open her pill bottle. She lives alone. She needs her medicine every four hours. How can she get the medicine she needs?

Another chart presents a short challenge statement or "design brief":

Design and make a device that will help Grandmother regularly receive her medicine.

Listen in as Ms. Clark visits with several teams. The first group is testing different construction materials and finishing a sketch of a proposed solution.

"At first we set up the design with a pill dispenser knob, but then we were thinking if Grandmother can't open a little pill bottle, how could she turn a knob?" a student is saying. "We need something that is easier to open—maybe we should try a lever or a pull string."

"Your device looks promising," says the teacher, looking at the sketch. "What are your ideas for materials and connections?"

"We tried gluing pieces of plastic," says Karen, "and that didn't work."

"What happened when you glued it?" inquires the teacher.

"Roberto had to hold the pieces together, and the glue dripped out when he squeezed it."

"What did you do then?" Ms. Clark probes.

"We decided to use brads to clip them together."

"Did that work?"

"We're still working on that part ..."

In another group three girls have a different solution. Made from a large cereal box and a spring-loaded delivery chute, their device connects to a timer and a switch that holds a trap

continued on page 2

Design in the Classroom.
continued

door shut. Pills, loaded in the top, will rattle down the delivery chute at timed intervals. The students clamor to demonstrate for the teacher:

"Look! Look! It almost works!"

Design: Constructive Thought and Action

Design in the science and mathematics classroom challenges students to apply their learning. Faced with a defined problem, students must use productive and critical thinking, analysis, decision making, and evaluation skills to produce tangible solutions. Design challenges can draw from a variety of disciplines and require a variety of responses. In some situations, students plan and build a product; sometimes, they analyze the solutions of others. Some classes take their ideas beyond the classroom and put them to work outside the classroom.

Science in schools should focus on discoveries children can make through inquiry; the best science educators permit a rich variety of these discoveries to co-exist and do not force the students to converge upon only one idea. Design is the technological parallel to inquiry. It offers students experience in planning and making models of useful things and introduces them to laws of nature through their understanding of how objects and systems work. It pursues solutions to problems: how to design an efficient boat hull, how to get across a river, or how to open a pill bottle with arthritic hands. Going back to the drawing board runs through the design process; troubleshooting and modifying plans, designing and building different models, and relying on teamwork strategies are integral to the spirit of the design classroom.

Science, mathematics, and ology are entwined in modern life. Practical manifestations of science and mathematics touch our lives many times each day. Integration of the disciplines, including aspects of social and historical concern, reflect the reality of our culture and the world our students will soon join as adults. Design assignments can pull together threads from many disciplines, certainly science and mathematics, but also social studies, language arts, and fine arts. The interactive cooperation required for successful group problem solving provides a practice ground for experiences in the adult workplace.

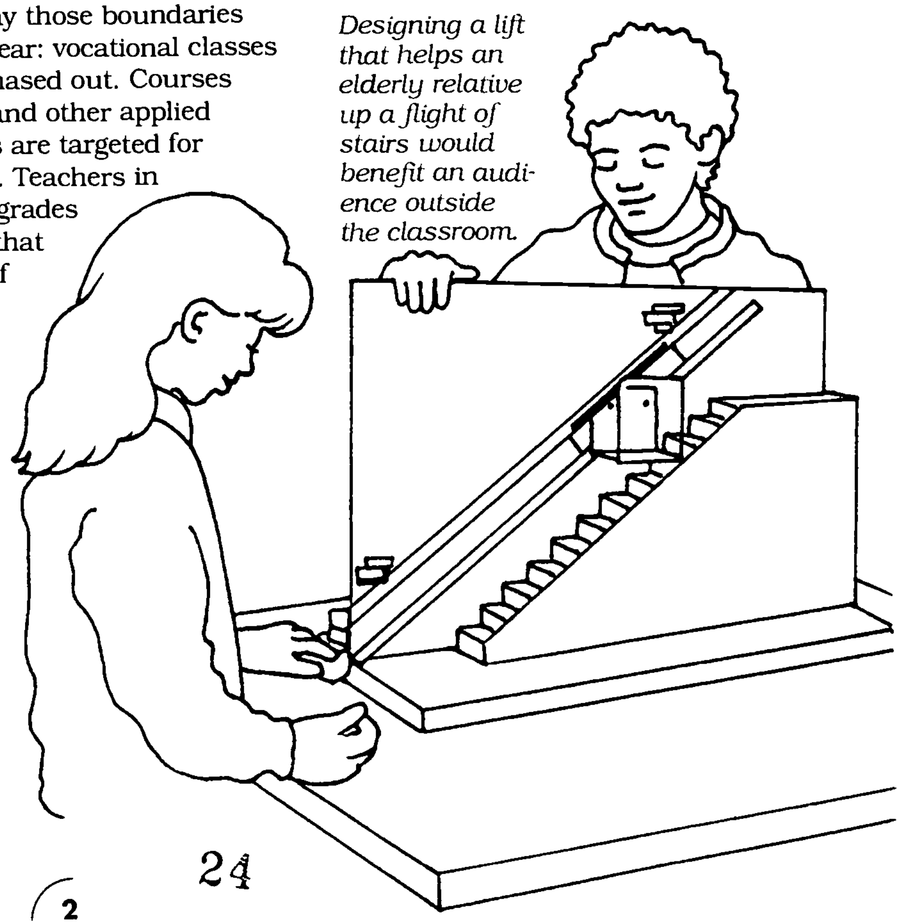
Design technology, a national curriculum in the United Kingdom, harkens back to the "practical arts" of American classrooms in the 1930s and 1940s. Once common in our schools, skills such as using tools and making decisions on craft materials became less important than academic pursuits in the 1950s and were eventually reserved for secondary students on vocational tracks. Today those boundaries seem less clear; vocational classes are being phased out. Courses in robotics and other applied technologies are targeted for all students. Teachers in elementary grades are finding that the basics of design are an exciting addition to their young students' curriculum. Science and mathematics teachers at all levels can use design projects to pose problems and encourage constructive thinking about solutions.

Problems are Everywhere

Teachers report that finding problems is a difficult step for students, but many problems can be identified in everyday living. Examples such as life's persistent hassles (travel time to work is increasingly slow because of traffic snarls), children's literature (the pigs' houses couldn't stand the wolf's huffing and puffing), and opportunities to improve our quality of life (fast food containers are filling up the landfill) provide opportunities for discussion and design solutions.

Some practice in brainstorming ideas and then suggestions that can be translated into an invention can help students build their skills in problem finding. Encourage them to jot down things that are nuisances. Here are a few: When an ice cube tray

continued on page 9



Designing a lift that helps an elderly relative up a flight of stairs would benefit an audience outside the classroom.

Stages in the Design Process

Design is a creative process that occurs in many settings. The steps outlined below offer a structured format for a formal design process based on models from industry.

Analyze the situation

Before beginning the design, sort out what problem you are trying to address.

Write a brief

Write a short statement giving the general outline of the problem to be solved.

Research the problem

Sometimes a problem can be solved "straight out of your head," but in most cases you will need to gain some new information and knowledge.

Write a specification

This detailed description of the problem spells out what the design must achieve and what limitations will affect the final solution.

Work out possible solutions

Combine your ideas with information obtained from your research to suggest several possible design solutions. Sketch several possibilities on paper.

Select a preferred solution

Decide which solution to develop. Although the chosen solution should, ideally, be the one that best satisfies the specifications, other constraints such as time, cost, or skills may limit the decision.

Prepare working drawings and plan ahead

Draw the chosen design including all the details that are important to its construction.

Construct a prototype

Make the product. In industry a model is usually built first and the final product is developed from it, but in most classrooms, the model is the final product.

Test and evaluate the design

Testing is ongoing as the construction progresses, but a final test of the entire system or model proves if the project does the job for which it is designed. Look back at the specifications and check the requirements carefully. Ask such questions as: How well does the design function? Does the design look good? Is the product safe to use? Were suitable materials used? How could I have improved on my design?

Write a report

The report provides evidence of your work in analysis, planning, designing, carrying out the practical work. evaluating, and communicating.

Science and Technology

Excerpts from the *National Science Education Standards*

Developing Student Abilities and Understanding

Grades K–4

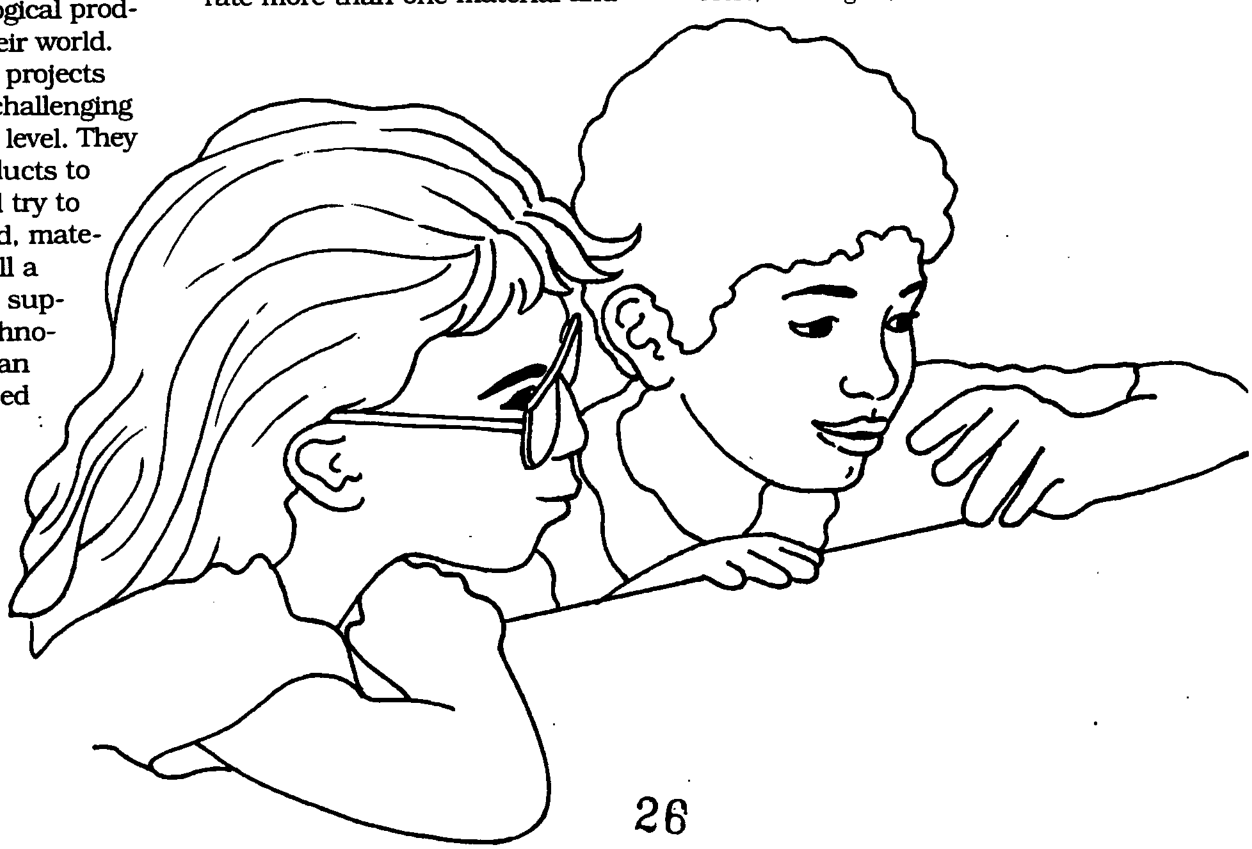
In grades K–4, children should have a variety of educational experiences that involve science and technology, sometimes in the same activity and other times separately. When the activities are informal and open, such as building a balance and comparing the weight of objects on it, it is difficult to separate inquiry from technological design. At other times, the distinction might be clear to adults but not to children.

Children's abilities in technological problem solving can be developed by firsthand experience in tackling technological tasks. They also can study technological products and systems in their world. Children can engage in projects that are appropriately challenging for their developmental level. They can study existing products to determine function and try to identify problems solved, materials used, and how well a product does what it is supposed to do. An old technological device, such as an apple peeler, can be used as a mystery object for students to investigate and figure out what it does, how it helps people, and what problems it might solve and cause. Such activities provide excellent opportunities to direct attention to specific technology—the tools and instruments used in science.

Suitable tasks for children at this age should have clearly defined purposes and be related with other content standards. Tasks should be conducted within immediately familiar contexts of the home and school. They should be straightforward; there should be only one or two well-defined ways to solve the problem, and there should be a single, well-defined criterion for success. Any construction of objects should require developmentally appropriate manipulative skills used in elementary school and should not require time-consuming preparations and assembly.

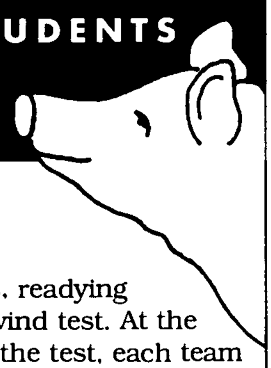
Over the course of grades K–4, student investigations and design problems should incorporate more than one material and several contexts in science and technology.

Experiences should be complemented by study of familiar and simple objects through which students can develop observation and analysis skills. By comparing one or two obvious properties, such as cost and strength of two types of adhesive tape, for example, students can develop the abilities to judge a product's cost against its ability to solve a problem. During the K–4 years, an appropriate balance of products could come from the categories of clothing, food, and common domestic and school hardware.



A DESIGN EXPLORATION FOR LOWER LEVEL STUDENTS

The Three Little Pigs



Early elementary students gain experience with construction techniques for strength and stability.

This activity uses a well-known children's story to introduce elementary students to some basics of structural support. Begin with a reading of "The Three Little Pigs" and a discussion of how the pigs constructed their houses. Have the students examine the structures like braces and trusses (triangles connected together) that support the tables and chairs in the classroom. You may want to let the students explore the world outside, looking at structures supporting, containing, and sheltering people and their belongings. A walking trip down the street reveals houses and transportation structures like bridges and walkways. The playground has structures to look at and the school building itself is supported by braces and pipes that may be hidden.

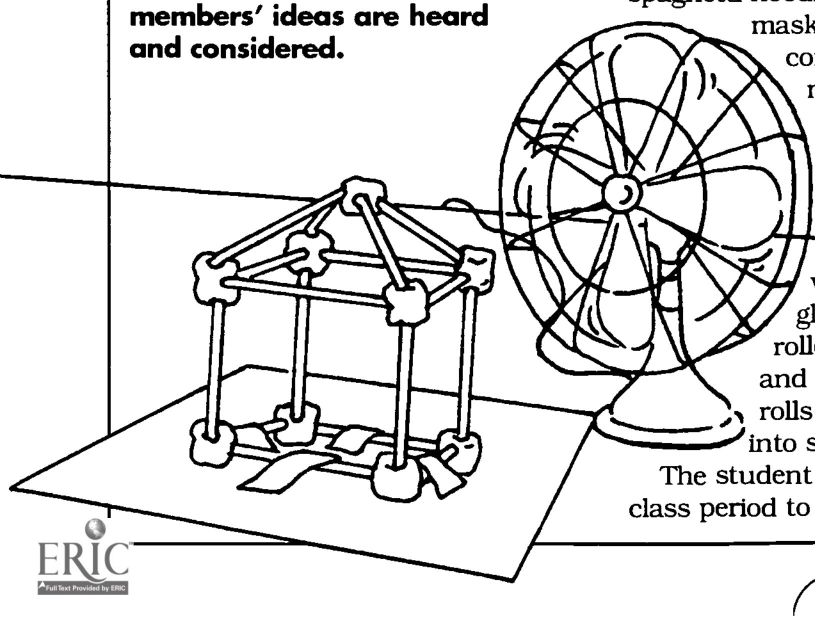
Encourage a variety of designs and building techniques in the children's structures. Design provides opportunities for experimentation.

Cooperative teamwork is essential to ensure all team members' ideas are heard and considered.

The Challenge: Design and make a shelter for three pigs that the wolf can not blow down.

Student teams may pick from three options for the shelter's main structural support: toothpicks, straws, or rolled paper. The builders may use only 16 total of whatever construction material they choose. Each house must be no taller than 15 cm (6″) and must fit into the "footprint," a 15 cm x 15 cm (6″ x 6″) square marked on the table. Each house must stand for three minutes when placed 7.5 cm (3″) in front of a fan.

One of the major challenges in this activity is ensuring that the structures are well enough anchored to the tabletop to withstand the fan's force. Provide a variety of construction and connecting materials to bolster the structures and secure their foundations. Possible materials are: glue sticks, staple gun, paper clips, marshmallows or gumdrops, spaghetti noodles, soaked whole dry peas, brads, and tape. Here are some methods that can work: straws attached with paper clips; spaghetti noodles attached with masking tape; toothpicks connected with marshmallows, gumdrops, or softened beans (let them dry overnight after poking toothpicks in them); wood sticks and glue; and paper rolled around pencils and taped, with the rolls taped together into structures.



The student teams will need a class period to design and build the structures, readying them for the wind test. At the completion of the test, each team should discuss its house and the reasons it stood or fell when the fan blew on it.

Data Collection

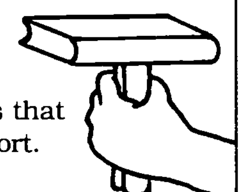
Use a large sheet of chart paper with columns headed MATERIAL, CONNECTOR, and RATING. Student teams fill out the data and rate the materials based on their building experience.

MATERIAL	CONNECTOR	RATING
Rolled paper	glue	fair
Rolled paper	tape	good
Toothpick	marshmallow	poor

Exploration

The students' houses have been tested by a force from the side, but many structures must withstand force from above. What structures are strong enough to bear weight?

Give pairs of students a piece of copy paper and a 15cm (6″) piece of tape. Let them try to shape the paper so a book can be placed on it at least 20 cm (8″) above the table. A column of paper will hold a balanced book. Continue to load books on the column until it collapses and let the students mark areas of weakness and strength in their design. This evidence of "buckling" helps illustrate stress points and areas that need more support.



This activity is adapted from: Fowler, M. *Beginning Lessons in Engineering Design: The DTEACh Classroom Lessons.* Austin, TX: Bar-None Publishing, 1994.

A DESIGN EXPLORATION FOR UPPER LEVEL STUDENTS

Power Boat Design

New initiatives in design and technology can influence school staff collaboration. This activity, Power Boat Design, is excerpted from a unit presented in Technology Science Mathematics (TSM) Connection Activities, *a curriculum of integrated design projects for grades 6 and up, published by Glencoe/McGraw Hill.*

This design project brings together science, mathematics, and technology, allowing in-depth exploration of design principles and the underlying mathematics and science that support them. Science units on buoyancy, Newton's Laws of Motion, and Archimedes' Principle are relevant to the boat's design and function. In mathematics, students need an understanding of surface area, volume, and symmetry as well as skills in graphing to complete the design, construction, and testing of their boats. Student designers also learn about energy conversion, boat hull design, drag, tools, and materials. The variety of options—materials, hull shapes, propulsion systems—assures that a selection of different boats will emerge from the design process.

Designing a Power Boat

Middle or high school students are challenged to design a self-propelled toy boat. They must choose boat materials, determine hull shape and a propulsion system, build the model, and conduct a variety of tests and measures to design an efficient craft. The following activity, one component of the design process, tests the boat's hull for efficiency and buoyancy.

The Test

The students will float their boats in a 2 m (6.5')-long trough filled with water to 1 cm (1/2 in) from the top. A plastic roof gutter, sealed to hold water, works well for this test. A pulley attached to one end of the gutter is threaded with a length of string weighted with a 150 g (5.25 oz) block. The string attaches to a boat's hull (see illustration below) and the weight drags the boat through the water. A start and finish line mark the distance for timing and a stopwatch records the speed. A photogate sensor provides a more technical option for recording the speeds.*

Presenting the Problem

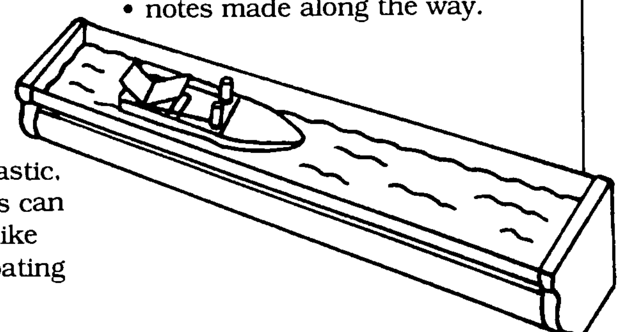
Design constraints for constructing the boat:

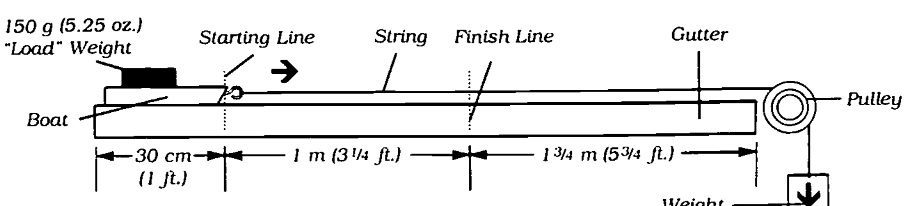
- A variety of materials may be used, including wood, plastic, or metal. Styrofoam™ blocks can be used. Porous materials, like wood sheet stock, need a coating to reduce water absorption. Coatings can make the hull smoother, reducing friction, and increasing performance.
- The boat can be no bigger that 8 cm (3.1") wide and 23 cm (9") long.
- The boat can have no pointed, sharp, or loose parts that might injure children.

The Design Portfolio

Require the design teams to document their work in a portfolio with the following materials:

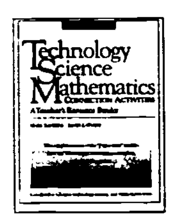
- information gathered from resources;
- drawings of all possible hull designs, providing views from the side, top, and bottom;
- tables, charts, or graphs showing how the boat performed;
- illustrations or descriptions of the science and mathematics principles used to design the boat;
- all technology, science, and mathematics work completed during the activity;
- notes made along the way.





*A photogate sensor is not essential to this activity. For further information about this tool, see page 8.

The complete 48-page Power Boat activity (ISBN: 0-02-636952-4) is available from Glencoe/McGraw Hill for \$3.21 plus postage and handling. The complete binder (ISBN: 0-02-636947-8) with six activities is available for \$61.98 plus postage and handling. For information call 1-800-334-7344.



Science and Technology

Excerpts from the *National Science Education Standards*

Developing Student Abilities and Understanding *Grades 5–8*

In the middle school years, students' work with scientific investigations can be complemented by activities in which the purpose is to meet a human need, solve a human problem, or develop a product rather than to explore ideas about the natural world. The tasks chosen should involve the use of science concepts already familiar to students or should motivate them to learn new concepts needed to use or understand the technology. Students should also, through the experience of trying to meet a need in the best possible way, begin to appreciate that technological design and problem solving involve many other factors besides the scientific issues.

Suitable design tasks for students at these grades should be well-defined, so that the purposes of the tasks are not confusing. Tasks should be based on contexts that are immediately familiar in the homes, school, and community of the students. The activities should be straightforward with only a few well-defined ways to solve the problems involved. The criteria for success and the constraints for design should be limited. Only one or two science ideas should be involved in any particular task. Any construction involved should be readily accomplished by the students and should not involve lengthy learning of new physical skills or time-consuming preparation and assembly operations.

Note that while the principles of design for grades 5–8 do not change from grades K–4, the complexity of the problems addressed and the extended ways the principles are applied do change.

Developing Student Abilities and Understanding *Grades 9–12*

Although these are science education standards, the relationship between science and technology is so close that any presentation of science without developing an understanding of technology would portray an inaccurate picture of science. Learning experiences associated with this standard should include examples of technological achievement in which science has played a part and examples where technological advances contributed directly to scientific progress. With regard to the connection between science and technology, students as well as many adults and teachers of science indicate a belief that science influences technology. This belief is captured by the common and only partially accurate definition "technology is applied science." Few students understand that technology influences science. Unraveling these misconceptions of science and technology and developing accurate concepts of the role, place, limits, possibilities, and relationships of science and technology is the challenge of this standard.

The choice of design tasks and related learning activities is an important and difficult part of addressing this standard. In choosing technological learning activities, teachers of science will have to bear in mind some important issues. For example, whether to involve students in a full or partial design problem, or whether to engage them in meeting a need through technology or in studying the technological work of others. Another issue is how to select a task that brings out the various ways in which science and technology interact, providing a basis for reflection on the nature of technology while learning the science concepts involved.

In grades 9–12, design tasks should explore a range of contexts including both those immediately familiar in the homes, school, and community of the students and those from wider regional, national, or global contexts. Successful completion of design problems requires that the students meet criteria while addressing conflicting constraints.

Over the high school years, the tasks should cover a range of needs, of materials, and of different aspects of science. For example, a suitable design problem could include assembling electronic components to control a sequence of operations or analyzing the features of different athletic shoes to see the criteria and constraints imposed by the sport, human anatomy, and materials. Some tasks should involve science ideas drawn from more than one field of science. These can be complex, for example, a machine that incorporates both mechanical and electrical control systems.

Although some experiences in science and technology will emphasize solving problems and meeting needs by focusing on products, experience also should include problems about system design, cost, risk, benefit, and very importantly, tradeoffs.

Resources and Opportunities

One way to find out more about design education in your state is to talk to the state education agency person in charge of technology education. These contacts can tell you about statewide initiatives, links with national efforts in technology education, and what might be going on in your local area.

Hervey R. Galloway
Arkansas Department of Education
Three Capitol Mall
Little Rock, AR 72201-1083
1-501-682-1271

Jerry O'Shee
Louisiana State Department of Education
PO Box 94064/Room 300
Baton Rouge, LA 70804-9064
1-504-342-1499

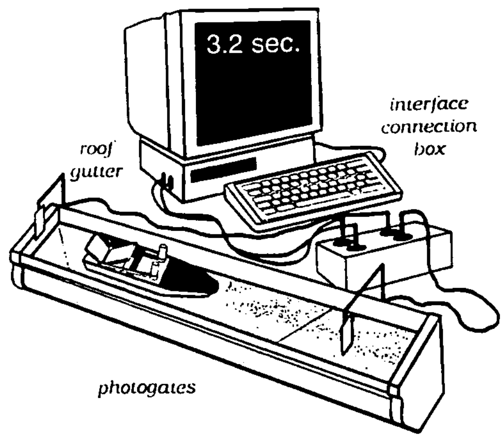
Karen Christopherson
New Mexico Department of Education
300 Don Gaspar
Santa Fe, NM 87501-2786
1-505-827-6662

Lynn Hawkins
Technology Education
1500 West Seventh Ave.
Stillwater, OK 74074-4364
1-405-743-5478

Richard Grimsley
Texas Education Agency
1701 N. Congress Ave.
Austin, TX 78701-1494
1-512-463-9688

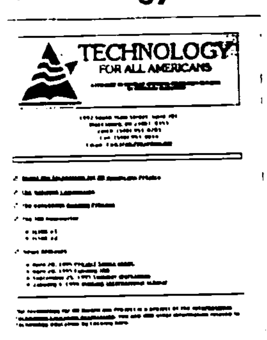
Photogate Sensor

A *Photogate Sensor* can be connected to a computer or a CBL (computer-based laboratory). The sensor system consists of an infrared light-emitting diode (LED) and an infrared light sensor. When an object passes between the light source and the sensor, the sensor sends a signal to the computer. For the power boat activity on page 6, set one photogate at the starting point and a second photogate at the finish point. The computer will record the elapsed time and



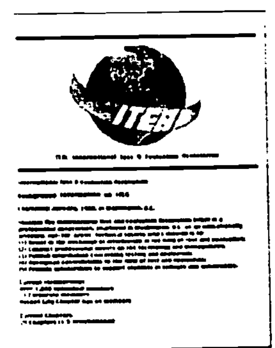
display it on the monitor. The boats must be equipped with a flag that will block the beam of light when the boat passes through the photogate. Photogates are available in kits or ready-made and range in price from a $23 kit to $75 assembled. Versions are adaptable to IBM, Apple II, and Macintosh computers; additional interface software will be needed.
Available from:
Vernier Software
2920 S.W. 89th Street
Portland, OR 97225
1-503-297-5317

Technology for All Americans



The National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) have funded the *Technology for All Americans* (TAA) project to develop national standards for K–12 education. Presently in Phase I, TAA is grappling with questions concerning the long-term vision for technology education and a clear definition of the intellectual domain it encompasses. Phase II will develop curriculum content standards for grades K–4, 5–8, and 9–12. All aspects of technology will be included in the standards as well as relationships with such allied disciplines as science, mathematics, and engineering.
For more information:
Technology for All Americans 1997 South Main Street
Suite 701
Blacksburg, VA 24061-0353
1-540-953-0203
Their Web address is
scholar.lib.vt.edu/TAA/TAA.html

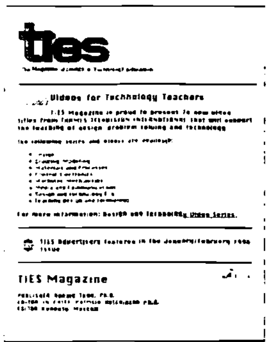
International Technology Education Association



The International Technology Education Association works on behalf of technology teachers, supervisors, administrators, and university personnel. Its purpose is to enhance technology education through experiences in schools, grades K–12. ITEA publishes *The Technology Teacher* and the *Journal of Technical Education*, as well as a variety of other publications and videos providing teaching directions, instructional ideas, and networking opportunities. For further information, contact:
ITEA's national office
1914 Association Drive
Reston, VA 22091
or check out their Web page at
www.tmn.com/Organizations/Iris/ITEA.html
1-703-860-2100

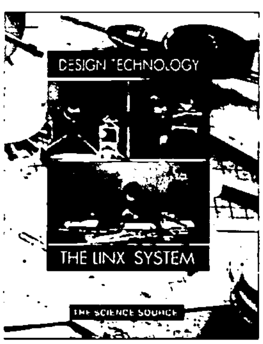
Ties: The Magazine of Design and Technology Education

For teachers of grades 6–12. *Ties: The Magazine of Design and Technology Education* offers a look at technology and design as a field of study in U.S. schools. *Ties* is a



nonprofit publication of Trenton State College, which offers an undergraduate degree program in technology education. The magazine is published six times a year and is free to teachers. It generally presents feature articles by teachers about their experiences. For more information write:
Ties Magazine
103 Armstrong Hall
Trenton State College
Hillwood Lakes CN 4700
Trenton, NJ 08650-4700
1-609-771-3333.
Or check out their Web page at
www.trenton.edu/~teched/ties.html

The Science Source



For a selection of kits, instructional activities, books, and tools that support design technology in the classroom, contact *The Science Source* and request a catalog of their materials. The library references available from this distributor include excellent publications from Great Britain that may be difficult to track down at your local bookstore. The Science Source also distributes the LINX™ System, a set of building/construction materials and the Collins Primary Technology series.
Address:
The Science Source
PO Box 727
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1-800-299-5469

Design in the Classroom,
continued from page 2

is emptied, one or two cubes often fall on the floor; feet can get too hot in the bottom of sleeping bags; too many drinking glasses may be used during the day; a dog's hair can get all over the chairs she rubs against. Can you think of inventions that could help solve these problems?

Literature can be a source for problems and inspire thinking about solutions and designs. "Three Billy Goats Gruff" is a good example. The goats want to cross the bridge, but a goat-eating troll always awakens and threatens them. How can we solve this problem? Perhaps the goats are too noisy crossing the wooden bridge. Is there another way to get across? Or a way to silence their hooves?

Social concerns can be another focus for design problem solving. For example, designing a lift that helps an elderly relative up a flight of stairs would benefit an audience outside the classroom. Rethinking the fabrication of toys to reduce use of raw materials or suggesting alternative routes to get to school are examples of design projects that could benefit the audience within the classroom. Critical thinking, imagination, and responsible action combine to produce rewarding and relevant classroom experiences.

Designing Solutions—from Kindergarten to High School

As children begin their school careers, they can tackle problems that are appropriate for their developmental level—for example, have young children think about and design new ways to fasten their coats or move through the room. They can also study technological products common to their world—zippers, bridges, or coat hooks. As they advance in the elementary years, problems and investigations should include more than one material and several contexts in science and technology. Students might make a device to shade eyes from the sun, compare two types of string to see which is best for lifting different objects, explore how small potted plants can be made to grow as quickly as possible, make yogurt and discuss how it is made, or design a simple system to hold two objects together. It is important to include design problems that require application of ideas, use of communications, and implementation of procedures—for instance, improving hall traffic at lunch or cleaning the classroom after scientific investigations.

During the middle school years, the design tasks can cover a range of needs, use a variety of materials, and draw on various aspects of science. Suitable experiences include making electrical circuits for a warning device, designing a meal to meet nutritional guidelines, choosing a material that combines strength with insulation, or designing a system to move dishes in a restaurant or in a production line.

Such work can be complemented by the study of technology in the everyday world. Investigating simple, familiar objects helps students develop powers of observation and analysis—for example, middle school students can compare the characteristics of competing consumer products, including cost, convenience, and durability. Regardless of the product studied, students need to understand the science behind it. Choose a variety of products including clothing, food, structures, and simple mechanical and electrical devices. Also include problems that are not concerned with products to help students understand that technological solutions include the design of systems (for example, traffic control design or recycling

continued on page 10

Design in the Classroom,

continued from page 9

solutions) and can involve communication, ideas, and rules.

At the high school level, students can participate in major design projects that deepen their understanding of technology and provide a richer sense of the links between technology, mathematics, and science. Students may perceive science as positive (as in "scientific progress") and technology as negative ("technological problems"). They may not be clear about the roles, limits, and relationships between technology and other disciplines. For example, technology can create a demand for new scientific knowledge. The availability of new technology often sparks scientific advances as scientists extend their research or try entirely new lines of inquiry.

High school projects should include familiar examples from the home, school, or community as well as problems from wider contexts—the nation, the world. Social and economic forces strongly influence which technologies will be developed and used and many factors, such as personal values, consumer acceptance, or the availability of risk capital, influence what and how products will be developed. At this level, students can examine ideas of risk analysis and technology assessment. Designed systems are often subject to failure but the risk of failure can be reduced by a variety of means: more research ahead of time, more controls, or fail-safe designs. The designer must balance a variety of issues including cost considerations, safety factors, and consumer acceptance with possible failures to determine the viability of developing the product.

Across all grade levels, design can be a purposeful, creative, and practical process of giving form to ideas. It fosters exploration and the application of relevant information to achieve something of value, and it can spark excitement and enthusiasm among students.

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

The Eisenhower SCIMAST project supports science and mathematics education in five states with a combination of training, technical assistance, networking, and information resources. Eisenhower SCIMAST is funded by the U.S. Department of Education's National Eisenhower Program to serve educators in Arkansas, Louisiana, New Mexico, Oklahoma, and Texas. Eisenhower SCIMAST works in partnership with the Eisenhower National Clearinghouse, a national resource center dedicated to increasing the availability and the quality of information about instructional resources for science and mathematics educators. As part of that effort, Eisenhower SCIMAST has a resource/demonstration center open to visitors Monday through Friday, 8:00 A.M. to 5:00 P.M. The center houses a multimedia collection of science and mathematics instructional materials for grades K–12. It is located on the fourth floor of the Southwest Educational Development Laboratory, 211 East Seventh Street, Austin, Texas 78701. The center also has a toll-free number, **1-800-201-7435**, that provides callers in the five-state region information on multimedia and print instructional materials, assessment tools, and successful strategies for mathematics and science instruction.

Eisenhower SCIMAST Staff:

Wesley A. Hoover, director
Glenda Clark, senior training associate
Marilyn Irving, senior training associate
Jackie Palmer, senior training associate
Barbara Salyer, senior training associate
Maria Torres, senior training associate
Jack Lumbley, evaluation associate
Kathy Schmidt, evaluation associate
Mary Jo Powell, technical writing associate
Sharon Adams, information associate
Lori Snider, administrative assistant
Veronica Mendoza, administrative secretary
Dawn McArdle, administrative secretary

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Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

Classroom Compass

Fall 1996 • Volume 2, Number 4

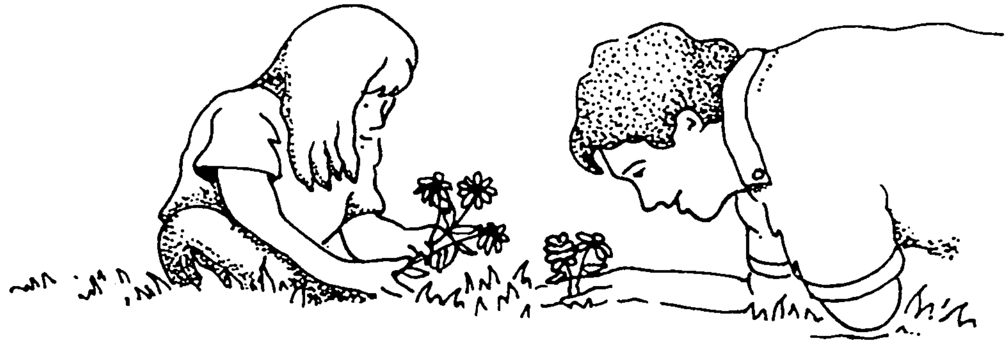
HIGHLIGHTS

Using Community Resources to Enhance Mathematics and Science Education

Jonathan is very excited. His fifth-grade class is visiting the Martinez Decorative Tile Company where his mother works. Near the end of the tour, Mr. Martinez challenges the students to create a design for a tiled wall the company has been asked to complete. If he can use the design, he will treat the class to a pizza party. Now it's Jonathan's teacher who is excited. What a perfect opportunity to introduce tessellations to the class.

Taking students on field trips or using other community resources in their classes is not a new idea for teachers. Often, however, these experiences are thought to be frills or rewards that compete with instructional time in the classroom. Curriculum reform in science and mathematics calls for a new look at using community resources. The national standards in science and mathematics suggest that good programs require access to the world beyond the classroom so that students will see the relevance and usefulness of science and mathematics both in and out of school. Changing the educational experiences of children by moving beyond the classroom walls can diversify the array of learning opportunities and connect school lessons with daily life and real problems.

Away from the structure of the classroom, many characteristics of constructivism, a key idea in the current reforms, clearly emerge. For example, imagine the interactions that occur as a small group of students experiments with an interactive museum exhibit. They talk about what they see and what they know, relating



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Using Community Resources to Enhance Mathematics and Science Education

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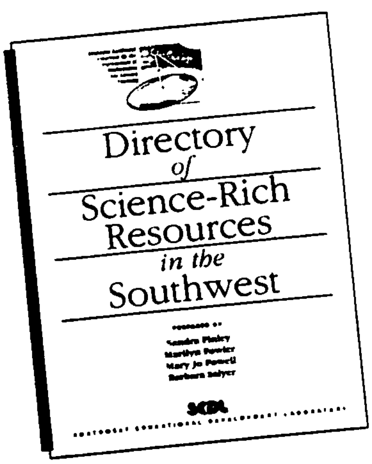
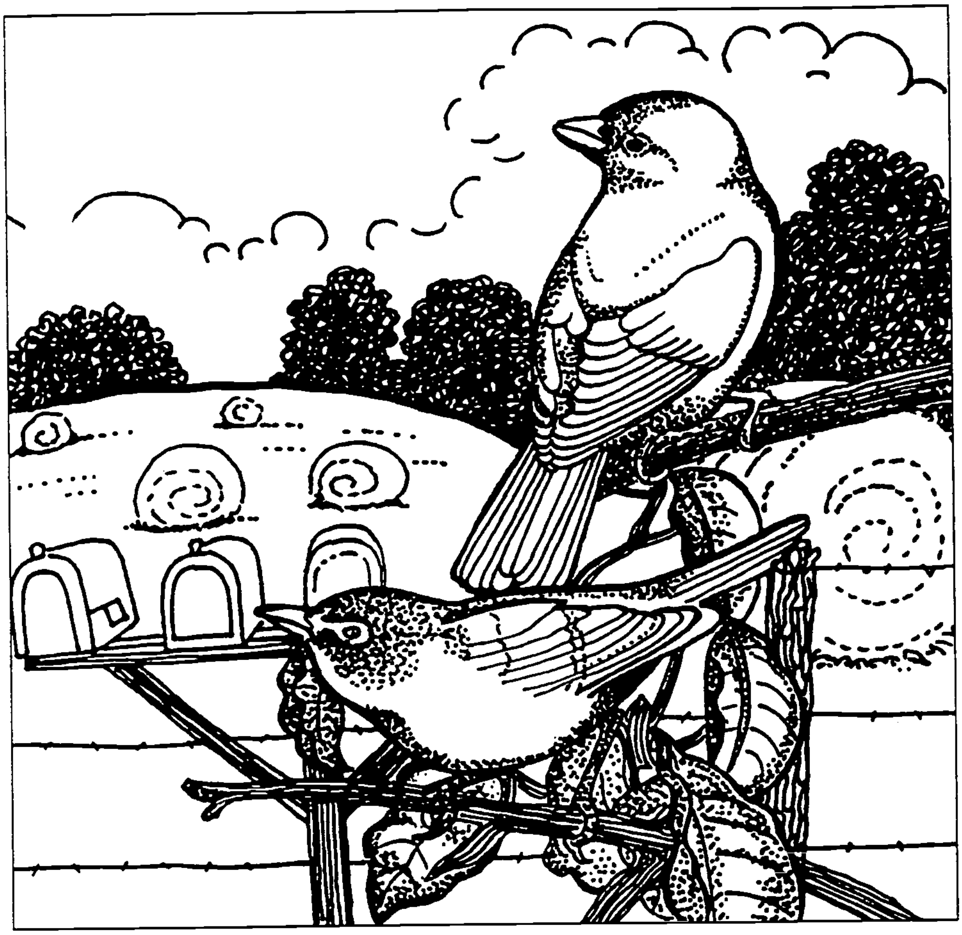
what they are doing in the museum to what they have learned in and out of class. They experience, create, and solve problems together. Social discourse and direct experience help them construct an understanding of the phenomenon. The exhibit puts constructivism in action.

Teachers always face the task of pulling together the diverse understandings their students bring to the classroom. The use of community resources provides a shared memory for the class. For example, going on a field trip is only part of the total experience. As students and teachers talk about the trip and think about it after it is over, they are building shared understanding. The event becomes part of the common knowledge of the class and can be referred to in subsequent lessons. What was learned is, thus, reinforced and extended in later discussions as the teacher refers to field observations.



*The *Directory of Science-Rich Resources*, a listing of museums, zoos, science centers, and other science-oriented resource locations in the Southwest can be ordered from the SCIMAST project as long as copies remain available. Call 1-800-201-7435 for information. The Directory is available on SEDL's World Wide Web site: **<http://www.sedl.org/>**.

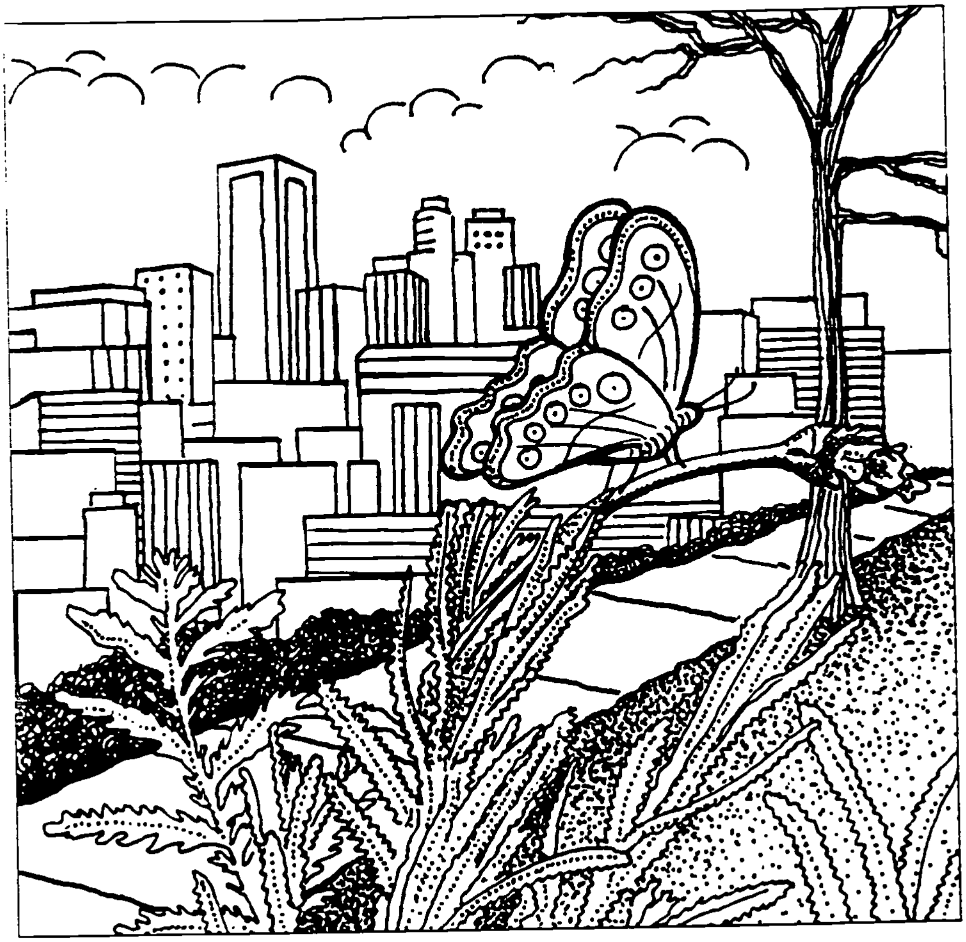


Teachers can effectively develop interdisciplinary units with their students outside of the classroom. The world is not made up of discrete disciplines. Students working on a city street, for example, could be doing social studies (e.g., making a survey of how a building is used today and how it has been used over the years), language arts (e.g., writing a short story about the building), mathematics (e.g., devising ways to measure the height of the building), and science (e.g., observing the materials used in the building for signs of weathering). Subject matter barriers dissolve as children learn from their environment.

Community resources that can enhance mathematics and science learning include science centers to visit (museums, nature centers, interactive science centers, aquaria, gardens and zoos), places to explore that are unique to the local school (a nearby creek, pond, city street or business), people in the community, or materials that can be borrowed or purchased. SCIMAST's *Directory of Science-Rich Resources** (called the Directory in the remainder of this article) can be used by teachers as a guide to science centers, sources of curriculum materials, and other kinds of science-rich resources in the region.

The Community beyond the Classroom Walls

Hector, Angela, and Melissa are around a resonant pendulum at the science museum. At this exhibit, they can affect the swing of the heavy pendulum by attaching weak magnets and pulling on the cord. Angela tries it and they notice that the swing of the pendulum gets larger when she pulls on the cord. Melissa tries it but her magnet falls off as soon as she pulls the cord. Together, they try to figure out what happened.



Outreach. Many students do not live near a zoo, nature center, or museum for a field trip to be practical, but numerous sites listed in the Directory offer outreach programs. A visit to your classroom by Wildlife on Wheels (Ellen Trout Zoo, Lufkin, Texas) or Creature Comforts (Little Rock Zoological Gardens, Little Rock, Arkansas) can be an engaging learning event for students.

Their class at City School is making a vegetation map of the city block. Shawna, Antoine, and Jennifer are recording the trees and shrubs in front of the school building and measuring their diameters when Antoine notices that little plants are growing out of the sidewalk cracks. They wonder if their map should include small plants as well as large ones and go to check with the group working around the corner.

Science Centers. A learning activity must have a purpose or reason so field trips should be thought of as part of the curriculum. As such, they should provide something to think about as well as something to do or some place to go. If possible, the teacher will want to visit the science center before the field trip to help her balance the needs of the teaching unit with the resources of the site. She can then focus on those exhibits that demonstrate the concepts she is teaching and match the students' cognitive levels. Learning activities are prepared for use before, during, and after the field trip and include student orientation material, such as a map, a list of exhibits to be visited (although they could visit others), and the educational objectives of the trip. This focused approach will advance student learning more effectively than an unfocused scavenger hunt or a generic worksheet written without the benefit of the teacher's preparatory visit. The Directory offers numerous examples of informal places that link to curricula. The Louisiana Children's Museum (New Orleans, Louisiana), for example, has an air hockey table adapted for experimentation with angular geometry, and the Texas State Aquarium (Corpus Christi, Texas) has a laboratory facility that demonstrates the physics of buoyancy and fluids.

Children generally find interactive exhibits engaging. These exhibits can be appealing and effective tools for teaching science and mathematics and for generating a positive attitude toward learning these subjects. At the Harmon Science Center (Tulsa, Oklahoma), students walk, climb and slide through the Underground Tulsa exhibit. At the Santa Fe Children's Museum (New Mexico), children use homing pigeons to send messages from an outside site to the museum.

Near the School. The lack of a nearby science center need not be a limitation. Community resources include unconventional sites, such as the tile factory or a hardware store, fabric store, farm, or ranch. While extended field trips can be rewarding, short school yard trips can be equally valuable. These allow children to discover answers for themselves in a familiar context. Whether your school is urban, suburban, or rural, it reflects the habitat of its neighborhood—the hard-topped surfaces, the soils, grasses, and trees, the weather, and so on. The young inquirer can easily return to the school yard for further data gathering if a question is left unanswered or new questions arise. A class studying the sun and its shadows in a particular location, for example, can gather data at intervals throughout the day.

continued on page 10

Environments for Learning Science

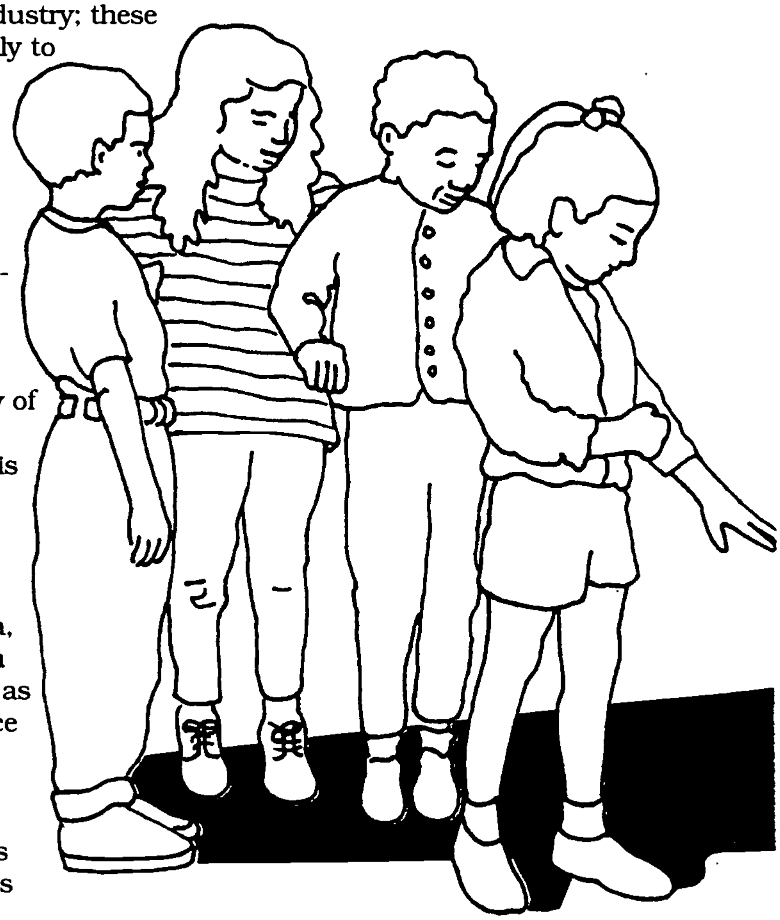
National Science Education Standards, Teaching Standard D

Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science.

Time, space, and materials are critical components of an effective science learning environment that promotes sustained inquiry and understanding. Creating an adequate environment for science teaching is a shared responsibility. Teachers lead the way in the design and use of resources, but school administrators, students, parents, and community members must meet their responsibility to ensure that the resources are available to be used. Developing a schedule that allows time for science investigations needs the cooperation of all in the school; acquiring materials requires the appropriation of funds; maintaining scientific equipment is the shared responsibility of students and adults alike; and designing appropriate use of the scientific institutions and resources in the local community requires the participation of the school and those institutions and individuals.

Teachers must be given the resources and authority to select the most appropriate materials and to make decisions about when, where, and how to make them accessible. Such decisions balance safety, proper use, and availability with the need for students to participate actively in designing experiments, selecting tools, and constructing apparatus, all of which are critical to the development of an understanding of inquiry.

The classroom is a limited environment. The school science program must extend beyond the walls of the school to the resources of the community. Our nation's communities have many specialists, including those in transportation, health-care delivery, communications, computer technologies, music, art, cooking, mechanics, and many other fields that have scientific aspects. Specialists often are available as resources for classes and for individual students. Many communities have access to science centers and museums, as well as to the science communities in higher education, national laboratories, and industry; these can contribute greatly to the understanding of science and encourage students to further their interests outside of school. In addition, the physical environment in and around the school can be used as a living laboratory for the study of natural phenomena. Whether the school is located in a densely populated urban area, a sprawling suburb, a small town, or a rural area, the environment can and should be used as a resource for science study. Working with others in their school and with the community, teachers build these resources into their work with students.



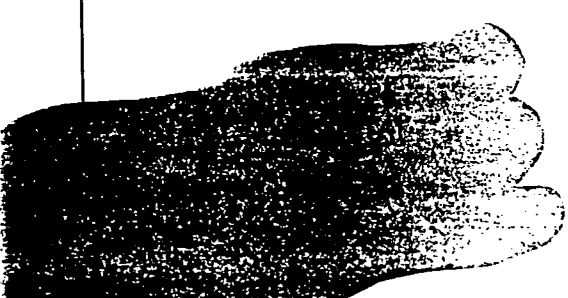
ACTIVITIES FOR ELEMENTARY STUDENTS

Learning From the World Outside the Classroom

Your school yard and its surrounding neighborhood is a laboratory where teachers and elementary students can actively investigate mathematics and science.

Teachers whose classes are not near such rich centers as museums or botanical gardens must use the local community as a source for science and mathematics learning. Short trips to the school yard that become an integral part of the class schedule can help students build an understanding of the natural world and increase their sophistication in observing and interpreting their surroundings. In fact, 10- and 15-minute field trips may be ideal for many topics. Students who develop skills working in groups, forming questions, collecting data, and observing their school yard laboratory will find that these experiences enhance their visits to other places as opportunities arise.

School yard explorations can focus on such topics as plants, trees, animals, the interdependence of living things, physical and chemical changes, sound, weather and climate, and geology. For example, shadow activities can enhance the study of the solar system and provide concrete experiences of the sun's influence on our planet.



- Let younger children explore shadows in the school yard. What is the largest shadow? What is the smallest? Put the children in a circle and have them count the number of shadows. Which way do all the shadows point?
- Use a thermometer with older students to compare the temperature difference in full sun and shadow. What conclusions can they draw from these measurements? What temperature differences might be plotted on the same location throughout the day? Throughout the week or month?

The outdoors can reflect mathematics principles as well. Data gathered by student teams may present more solid examples than textbook representations.

- The size of a shadow is directly proportional to the size of an object. Therefore, if a 1-meter ruler held perpendicular to the ground throws a 66-centimeter shadow and a tree shadow is 5.5 meters long, the tree's height can be calculated to be 8.33 meters (66:100=5.5:x). Try these calculations at different times of the day and at different times of the year.
- Let the students discover the constant π. Send teams of students outside to measure circular objects: trees, flagpoles, trash cans, utility poles. They may want to use yarn or string or a tape measure to wrap around the object for measurement of the circumference. To determine the diameter, use three yardsticks or meter sticks. Place a stick on each side of the object, making sure the two sticks are parallel and at the same height from the ground. Then use the third stick to measure the distance between the extended portions of the two parallel sticks—that is the diameter. The teams can post the measurements for their various objects on a statistical table. They may also want to note the radius for each of the objects. Ask the students to look at the data and see if they notice any special relationships among the various measurements. Ask each team to divide the value for the circumference by the value of the diameter and post the results. The constant π, 3.14 or 3 1/7, will emerge from these results.

For more ideas on using resources outside the classroom, see **Ten-Minute Field Trips** by Helen Ross Russell (1990). These have been used with permission of the National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201. Cost: $16.95 + $4.95 s/h (1-800-722-6782).

AN ACTIVITY FOR UPPER LEVEL STUDENTS

Using Mathematics in Fossil Reconstruction

This activity from a SCIMAST professional development event sent the participants on a mathematical exploration in a local natural science museum.

A display at the Texas Memorial Museum on the University of Texas at Austin campus presents several wing bones of a pterosaur believed to be the largest flying animal that ever existed—*Quetzalcoatlus northropi* (Qn). The museum's reconstruction of the animal's wing incorporates fragments, an intact humerus and several bone pieces that were found in the Big Bend National Park in Texas in 1971. How would scientists predict the pterosaur's probable wingspan from these pieces?

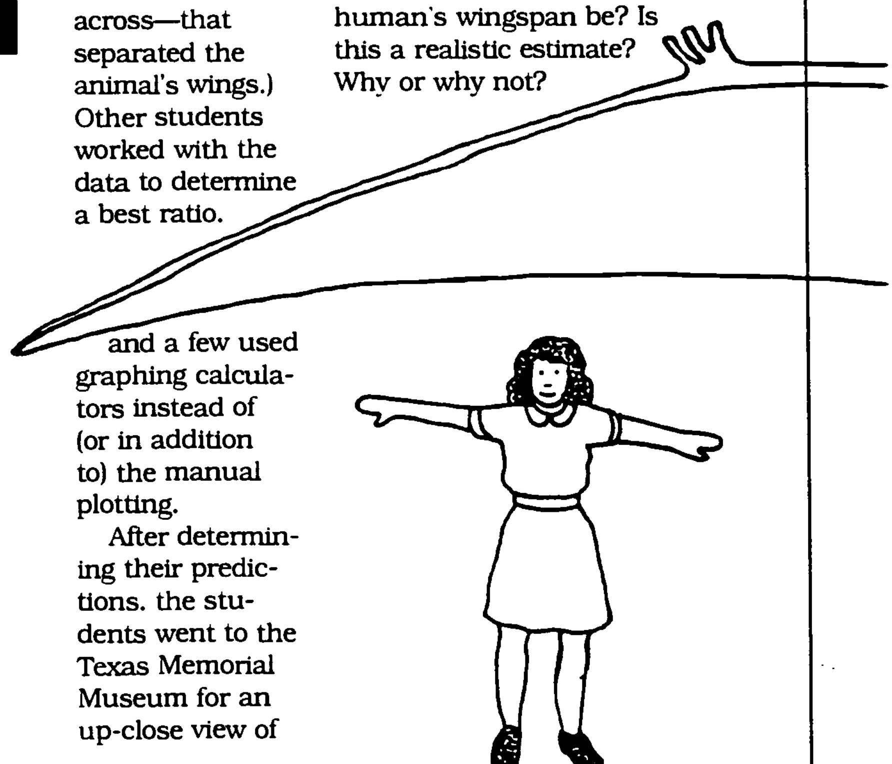
Data from similar pterosaurs found throughout the world were available from museum sources. These provided a glimpse of the creatures' proportionality and helped the students construct a table that compares wingspan and humerus lengths.

Taking the two variables provided, length of humerus and total wingspan, students were able to estimate the total wingspread of *Quetzalcoatlus northropi.* The data plotted on graph paper provided a scatter plot used by the students to determine the line of best fit. This linear regression provided a best estimate from the Qn humerus length. (To determine the entire wingspan, students had to factor in the pectoral girdle—estimated at .5 meter across—that separated the animal's wings.) Other students worked with the data to determine a best ratio, and a few used graphing calculators instead of (or in addition to) the manual plotting.

After determining their predictions, the students went to the Texas Memorial Museum for an up-close view of the wing fragments and the opportunity to measure the reconstructed left wing. While the students' predictions did not exactly match the reconstructed animal (because the line of regression only provides a "best possible fit"), the museum's reconstruction was within the graphed possibilities.

Lingering questions: Why was the estimate not exactly the same as the museum's reconstruction? What does the "best possible fit" mean? Would it be reasonable to use the pterosaur data to estimate the wingspan of a bird or a bat? If we measure our own humerus, and use the pterosaur correlation table, how wide would a human's wingspan be? Is this a realistic estimate? Why or why not?

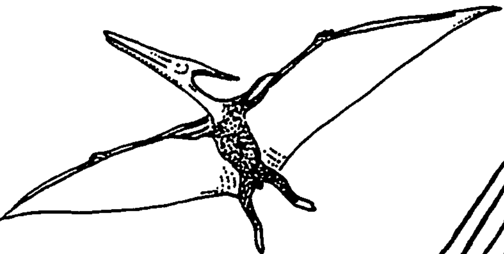
Pterosaur	Humerus Length	Total Wingspan
Quetzalcoatlus northropi	54 cm.	???
Quetzalcoatlus sp (small)	24 cm.	600 cm.
Ornithodesmus	20 cm.	500 cm.
Pteranodon	32 cm.	750 cm.
	27 cm.	570 cm.
	22 cm.	430 cm.
	15 cm.	300 cm.
Santanadactylus	17 cm.	370 cm.
Nyctosaurus	15 cm.	310 cm.
	13 cm.	270 cm.
	9 cm.	240 cm.
Pterodactylus antiquus	4.4 cm.	68 cm.
	3.6 cm.	55 cm.
	3.2 cm.	53 cm.
	2.9 cm.	50 cm.
	1.5 cm.	24 cm.

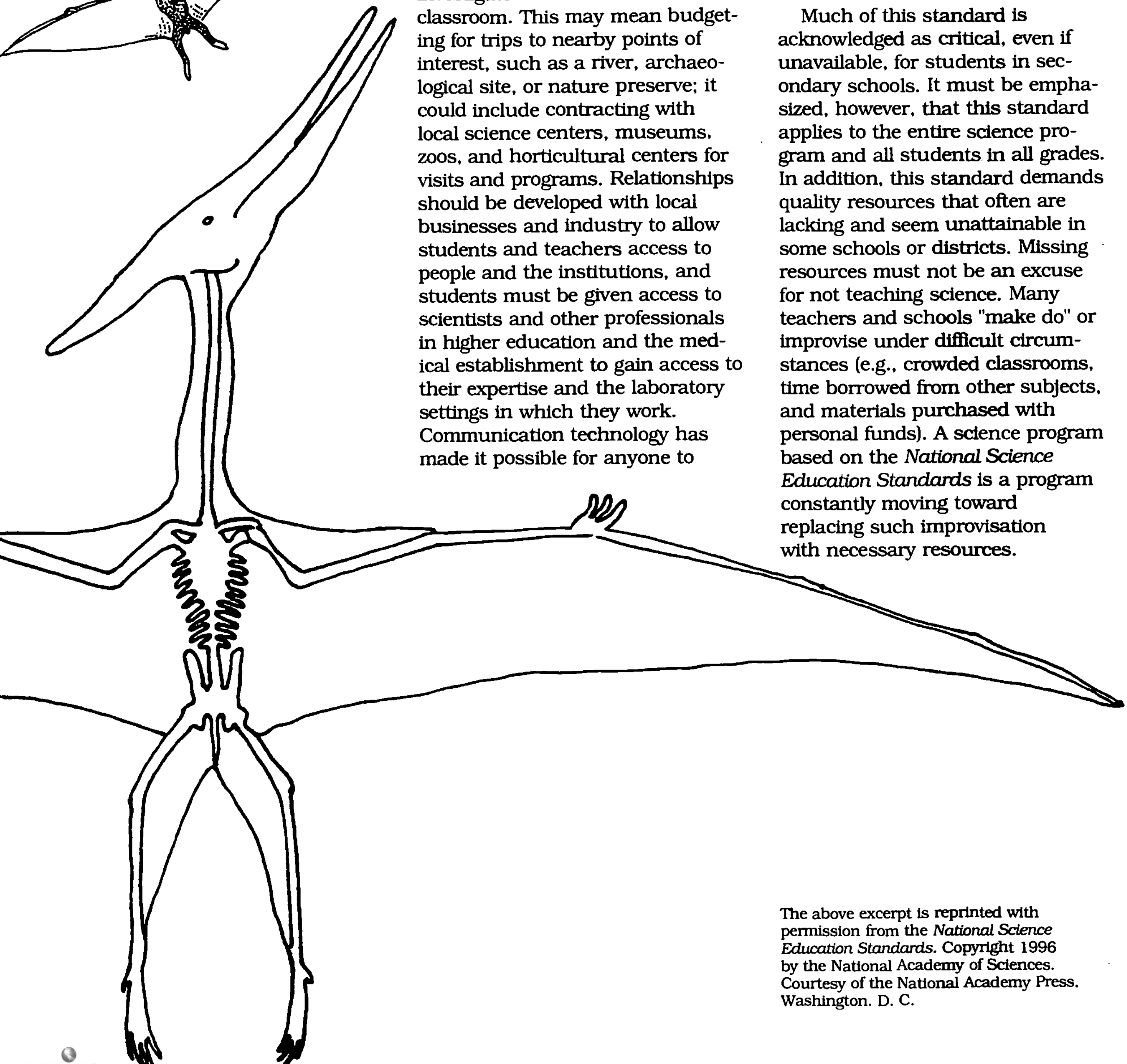


The World Beyond the Classroom

National Science Education Standards, Program Standard D

Good science programs require access to the world beyond the classroom.

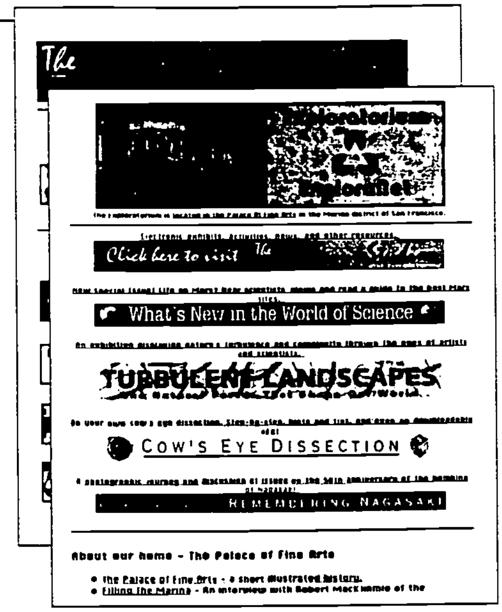




District and school leaders must allocate financial support to provide opportunities for students to investigate the world outside the classroom. This may mean budgeting for trips to nearby points of interest, such as a river, archaeological site, or nature preserve; it could include contracting with local science centers, museums, zoos, and horticultural centers for visits and programs. Relationships should be developed with local businesses and industry to allow students and teachers access to people and the institutions, and students must be given access to scientists and other professionals in higher education and the medical establishment to gain access to their expertise and the laboratory settings in which they work. Communication technology has made it possible for anyone to access readily people throughout the world. This communication technology should be easily accessible to students.

Much of this standard is acknowledged as critical, even if unavailable, for students in secondary schools. It must be emphasized, however, that this standard applies to the entire science program and all students in all grades. In addition, this standard demands quality resources that often are lacking and seem unattainable in some schools or districts. Missing resources must not be an excuse for not teaching science. Many teachers and schools "make do" or improvise under difficult circumstances (e.g., crowded classrooms, time borrowed from other subjects, and materials purchased with personal funds). A science program based on the *National Science Education Standards* is a program constantly moving toward replacing such improvisation with necessary resources.

Resources and Opportunities



Ten-Minute Field Trips

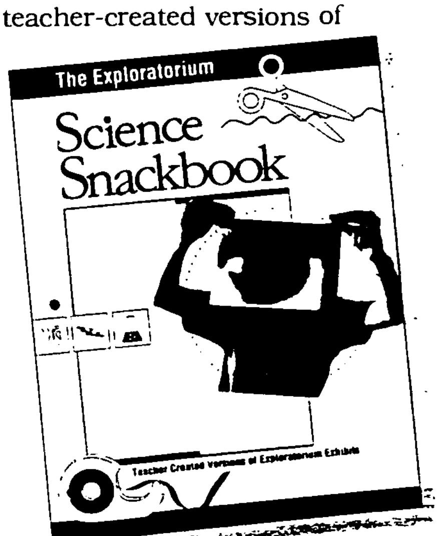
by Helen Ross Russell
National Science Teachers Association
$16.95 + $4.25 s/h
1-800-722-6782

This collection of activities, ideas, and examples urges teachers to explore the environments around their schools, whether urban, suburban, or rural. In addition to more than 200 short, close-to-home field trips, the author provides introductions that support an understanding of what might be seen during the students' explorations. The book is divided into topic sections—Plants, Animals, Interdependence of Living Things, Physical Science, Earth Science, and Ecology—and includes a special cross-referenced list of field trips for hard-topped school grounds. The preface, "Saying 'I Don't Know,'" sets the tone for teachers who will join their students in discovering the world outside their classrooms.

Exploratorium Teacher Institutes

The Exploratorium is an interactive science museum founded in 1969 by Frank Oppenheimer, noted physicist and educator. The center, located in the heart of San Francisco, presents hundreds of interactive exhibits and a variety of programs for children and adults. Every summer the Exploratorium offers 300 science teachers, grades 6–12, the opportunity to take part in a summer experience called the Teacher Institute. These intensive, two-, three-, and four-week programs provide a mix of content-based discussions, classroom experiments, and teaching strategies based on the Exploratorium's exhibits. Applications for admission to the summer 1997 Institutes are being accepted until April 1997. For those teachers accepted, tuition will be borne by the Exploratorium. For more information, take a look at the Exploratorium Web page **<www.exploratorium.edu>** or contact Exploratorium Teacher Institute, 3601 Lyon St., San Francisco, CA 94123. Phone: 415-561-0313

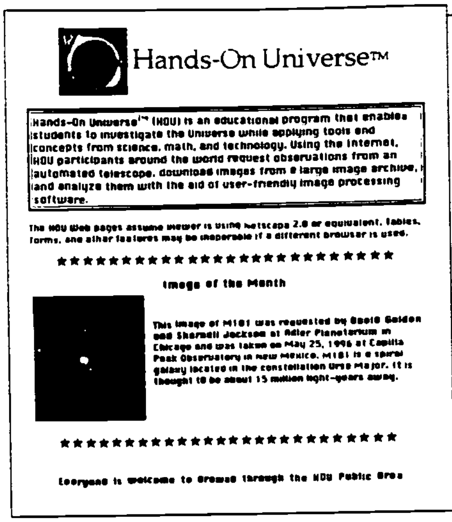
You can use materials created by these institutes if you get copies of the four-volume Exploratorium ***Science Snackbook*** Series, a collection of more than 100 teacher-created versions of Exploratorium exhibits. The books provide instructions for classroom-based constructions (balancing a ball on a stream of air, building a light-scatter box) that illustrate such concepts as magnetism, polarization, and refraction.



- *The Cheshire Cat and Other Eye-Popping Experiments on How We See the World*
- *The Cool Hot Rod and Other Electrifying Experiments on Energy and Matter*
- *The Magic Wand and Other Bright Experiments on Light and Color*
- *The Spinning Blackboard and Other Dynamic Experiments on Force and Motion*

Published by John Wiley and Sons, the books are available for $10.95 each plus shipping from the Exploratorium Mail Order Dept., 3601 Lyon Street, San Francisco, CA 94123 (415-561-0393) or from the publisher.

Also of interest to classroom teachers is ***The Exploratorium Guide to Scale and Structure; Activities for the Elementary Classroom***. The activities are starting points for exploring the physics and mathematics of structure as well as the effects of scale on structure. The book sells for $29.50 and is available from Heinemann publishers, 361 Hanover Street, Portsmouth, NH 03801-3912 (1-800-541-2086). It can also be ordered from the Exploratorium Mail Order Department.



Hands-On Universe

For the past four and a half years this program, with the support of the National Science Foundation and the Department of Energy, has enabled high school students to request their own observations from professional observatories. The students download images to their classroom computers and use powerful HOU software to visualize and analyze their data. Until recently the project has forwarded all requests to the Leuschner Observatory at the University of California Berkeley astronomy department. New collaborations between observatories in Hawaii, Illinois, California, Washington, Sweden, and Australia will provide a network of automated telescopes that can respond based on such conditions as geography, weather conditions, scheduling, and equipment characteristics.

Exciting results can occur when students are given access to this powerful equipment, as witnessed when two high school students requested observations of the Whirlpool Galaxy as part of their lesson on spiral galaxies. Their observation captured the first light of SN1994I, a supernova. Their names will appear as co-authors on a photometry paper about SN1994I.

For more information about this project, write: Hands-On Universe, MS 50-232 Lawrence Berkeley Lab One Cyclotron Road, Berkeley, CA 94720 or email **houstaff@ hou.lbl.gov**. The Web page address **<hou.lbl.gov/newpages/ ıtitle.html>**

Eisenhower Southwest Consortium for the Improvement of Mathematics and Science Teaching

The Eisenhower SCIMAST project supports science and mathematics education in five states with a combination of training, technical assistance, networking, and information resources. Eisenhower SCIMAST is funded by the U.S. Department of Education's National Eisenhower Program to serve educators in Arkansas, Louisiana, New Mexico, Oklahoma, and Texas. Eisenhower SCIMAST works in partnership with the Eisenhower National Clearinghouse, a national resource center dedicated to increasing the availability and the quality of information about instructional resources for science and mathematics educators. As part of that effort, Eisenhower SCIMAST has a resource/demonstration center open to visitors Monday through Friday, 8:00 A.M. to 5:00 P.M. The center houses a multimedia collection of science and mathematics instructional materials for grades K–12. It is located on the fourth floor of the Southwest Educational Development Laboratory, 211 East Seventh Street, Austin, Texas 78701. The center also has a toll-free number, **1-800-201-7435**, that provides callers in the five-state region information on multimedia and print instructional materials, assessment tools, and successful strategies for mathematics and science instruction.

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Using Community Resources to Enhance Mathematics and Science Education
continued from page 3

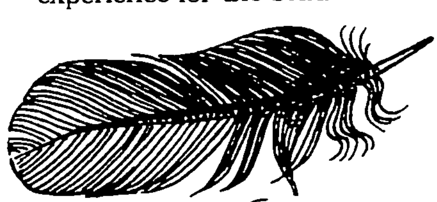
Bringing the Community into Your Classroom

Materials through the Mail. By necessity, most learning activities occur in the classroom. Organizations listed in the Directory can provide materials that enrich the curriculum and provide unique experiences for children. These inexpensive or free materials may be overlooked since they are not produced by educational publishing companies. Diaries in the Dirt, a program available from the Oklahoma Archaeological Survey, includes a set of artifacts for sand box explorations. Techniques, Technology, and Trade, a curriculum available from the Arkansas Ag in the Classroom State Leader, integrates science and economics. Numerous national organizations have also developed curriculum materials; guidance materials from professional organizations are useful ties to the workplace.

Electronic Connections. Many entries in the Directory have activities and programs that involve the Internet or e-mail communication and can be valuable additions for classes that have Internet access. Marsville, a project sponsored by Phillips Laboratory (Albuquerque, New Mexico), is a simulation for elementary classes. Students create prototypes of a colony on Mars and communicate by e-mail with other participating schools about colony operations. In the GLOBE Program, students take environmental measurements and post their data on the Internet. WeatherNet, listed under National Weather Service in the Directory, is an Internet resource that includes weather data and links to the home pages of more than 300 weather-related organizations.

Sharon likes mathematics, but she did not even know what a civil engineer did until Ms. Davies and Mr. Garcia came to her class. Now she thinks she would like to be one. The activity they did with the class about bridges intrigued her. After the class, she asks Ms. Davies about her bridge activity and then asks about colleges and jobs for girls in this field.

Guests. Guest speakers from the community can provide new information and experiences to students and link the school to the world outside. The teacher should spend time with the guest before the visit so they can discuss the age level of students and kinds of activities and information appropriate for this age group; the needs of the guest during the visit and his or her general comfort level with children; the topic of the presentation and the students' general knowledge about this topic; and what the teacher can do before to make the visit a success. Staff of state agencies can serve as classroom partners or as knowledgeable resource people. For example, staff from a conservation agency might be able to aid schools in setting up an outdoor classroom or civil engineers from the highway department may be able to show plans for a bridge project. Many potential speakers are overlooked, however, because they work in less technical fields. Valuable links to the community as well as connections between school subjects and the workplace may be created by inviting a cafeteria worker who could talk about using proportions in increasing the size of recipes. A mechanic or the owner of a feed store are other possibilities. Guests who can come back to the classroom numerous times may enhance the learning experience for the students.



Conclusion

The richness of the region's resources is apparent from the number and diversity of entries found in the *Directory of Science-Rich Resources.* Imagination and creativity in using community resources can help students connect school science and mathematics with applications in the community, as well as helping students better learn basic concepts. Children learn science and mathematics from many sources, in a range of different ways, and for a variety of purposes. Taking students to a science museum or out onto the school grounds, exposing them to innovative materials, or inviting guests who can give unique insights are a few ways to increase their learning experiences.

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