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THIS ISSUE’S FOCUS

Good Science, Good Math
Good Science, Good Math

Are we maintaining the levels of creativity and innovation in math and science teaching that can provide motivation and encourage ongoing inquiry and problem solving? An answer to this question may involve national and state initiatives, school and classroom goals and demands, teacher skills and energy, along with a host of minor factors that often become major, including such things as adequate funds for manipulative materials or funds for a field trip.

Some authors in this issue of Connect identify trends that may point to erosion of creativity in the face of multiple challenges to schools. Two articles address the hazards of high stakes summative assessments. Yet, every author cites examples of outstanding work on the part of teachers and students engaged in exemplary, inquiry-based investigations. The newest challenge may be to integrate effective practices with recent demands for greater accountability.

We hope these articles will provide points of discussion for many educators.
Highly qualified teachers all across the nation are interpreting the national standards for math and science, unpacking the essential learning for their grade level, and using a variety of authentic, performance-based assessments to guide their classroom practice. At the same time, they are preparing students to take standardized high-stakes, multiple-choice tests that ask students to recall basic facts and information. Which approach will leave students behind? What content is worth knowing?

We all agree that our students should be scientifically literate and mathematically fluent. The business community needs workers who can learn, reason, think creatively, make decisions, and solve problems. The goals of the National Science Standards are to educate students who are able to:

- Experience the richness and excitement of knowing about and understanding the natural world;
- Use appropriate scientific processes and principles in making personal decisions;
- Engage intelligently in public discourse and debate about matters of scientific and technological concern;
- Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers.

The goals of the National Mathematics Standards are to educate students who:

- Build new mathematical knowledge through problem solving;
- Make and investigate mathematical conjectures;
- Develop and evaluate mathematical arguments and proofs;
- Communicate mathematical thinking coherently and clearly to others;
- Recognize and apply mathematics in contexts outside of mathematics;
- Create and use representation to organize, record, and communicate mathematical ideas.

These national goals and standards are aligned with best practice, brain research, and instructional strategies that increase student achievement. The National Science Teachers Association and National Council of Teachers of Mathematics define who (every child) should learn what (the content standards) and how (the process standards). The verbs in these standards are experience, engage, build, apply, create, and communicate. One of the goals of the No Child Left Behind Act was to focus instruction and assessment on these standards and state benchmark outcomes. Therefore, in theory, teachers who...
implement these standards help their students learn science and math by actively engaging in inquiries that are interesting and important to them. The students construct a knowledge base for understanding science and mathematics in relationship to other disciplines.

**Just three, forty-hour weeks**

Are we teaching for understanding or for achievement on standardized tests, and do we have to choose one or the other? With so much to teach and so much to learn, the task of achieving both goals for our students is daunting. If the school year has 180 days, and we allocate time for testing, announcements, assemblies, and professional development days, this leaves us about 160 days of teaching. If we schedule 45 minutes for each subject, each day, it would add up to 120 hours of instruction in each subject, each year. Given three, forty-hour workweeks, would we teachers be able to master complex subject matter? How much can we reasonably expect all of our students to learn in that time?

Coherence is the key to helping students build the conceptual frameworks that help them retrieve knowledge and transfer knowledge to new contexts. Curriculum that allows adequate time for in-depth learning that is connected to “big ideas” in several content areas offers teachers a sound approach to teaching to the standards, increasing student understanding, and making “adequate yearly progress.”

Towards this goal, many teachers sought a standards-based curriculum that integrates math, science, language arts, and even social studies, while promoting both conceptual understanding and basic skills. *Bridges in Mathematics*, published by The Math Learning Center in Salem, Oregon, was developed with initial support from the National Science Foundation. This problem-centered curriculum includes a variety of manipulatives and visual models that facilitate the development of students’ mathematical thinking and reasoning. Some of the investigations grow out of ventures into the everyday world—reading stories, creating models, playing games, making quilts—while others delve more deeply into the world of mathematics itself. Students at all grade levels are encouraged to explore, develop, test, discuss, justify, and apply mathematical ideas.

**Skills mastery within a context**

The units in *Bridges* focus on related topics across multiple mathematical strands at once, for example, by having students master the basic facts in the context of investigating the algebraic patterns among them, or by developing strategies for multiplying larger numbers while exploring the volume of rectangular solids. The curriculum integrates fiction and non-fiction trade books and science and social studies themes throughout the year. Several life and physical science units integrate mathematics, literacy, and social studies standards at each grade level. The emphasis in primary classrooms is generally reading and writing literacy, and teachers frequently feel like they don’t have enough

*In primary grades, students use insect and spider manipulatives to help with their investigations.*
By remaining open to new ideas and strategies, these students are encouraged to do their best work and focus on being a community of learners.

Students gathering data

In primary grades, students investigate bugs, sea creatures, penguins, farm animals, and frogs and toads over the course of a few weeks. Students gather information, observe and record their findings, compare and contrast these creatures, read non-fiction text, and sing about praying mantises, “hanging upside down, wriggling out of old skin and making foam egg cases.”

The emphasis is on creating excitement for the child’s natural world, and learning that lasts. My students love comparing the height and weight measurements of different kinds of penguins. They learn to use a thermometer in order to measure the water temperatures that represent the oceans of the world.

Second graders build courses on which they roll marbles to explore the impact of different variables, including the marbles’ mass, tube length, and ramp height. They consider principles of balance and motion to make conjectures, investigate what actually does happen, and record their results in a variety of ways. Then they compare their data with other students to reach conclusions about the impact of true experimental design. Some scientific concepts are intuitive, and my students predict that the marble and wood bead will not roll as far as the steel ball bearing because it is heavier.

After each team performs three trials, we collect the data. They are pleased when they compare data with their predictions. We place the same marble into tubes of varying lengths (toilet paper, paper towel and gift wrap) and send them rolling. Many student predictions are not confirmed, and they spend their free time trying to figure out why. Without pre-planned units such as these, many primary class-

rooms would be void of any real physical science experiences. My test scores were not compromised by taking time for these experiences because my students knew how to make connections and think critically about a problem solving situation.

In Bridges, third graders learn about different kinds of bridges, build their own model bridges while making conjectures, and draw conclusions about effective bridges design and construction. My students are astonished at how many wood cubes can be balanced on a paper beam bridge. They challenge each other to make a stronger, longer bridge that could carry a larger load. Students grapple with the many variables that influence the length and strength of bridge designs, and quantify them by estimating, measuring, and testing the strength of their own models. By remaining open to new ideas and strategies, these students are encouraged to do their best work and focus on being a community of learners.

Supportive evidence

The National Assessment of Educational Progress data supports teaching mathematical reasoning and emphasizing complex topics in the curriculum. Teaching that emphasizes higher-order thinking skills, project-based learning, opportunities to

Students build their own model bridges, drawing conclusions about effective bridge design and construction.
solve problems that have multiple solutions, and the application of hands-on techniques, such as using manipulatives, were all associated with higher performance on the mathematics NAEP. The Trends in International Mathematics and Science Study (TIMSS) provides further evidence. The NAEP data for science achievement suggest that teaching for meaning and focusing on projects in which students take on a high degree of initiative positively impacts student success. Completing worksheets and reading from textbooks does not.

At a time when we are asking teachers to place more emphasis on understanding by teaching in the context of inquiry, applying technology in a meaningful way, and integrating content areas, a viable curriculum can help meet the demands. With *Bridges in Mathematics*, students investigate and analyze questions over an extended period of time, construct original arguments and explanations, and defend their conclusions.

_Pia Hansen Powell, a veteran elementary teacher, now leads professional development workshops in mathematics and coaching and presents at national conferences. She has taught at the University of Wyoming and authored _Buddies_, a book about cross-grade mentoring. Pia wrote the third-grade curriculum for Bridges 2003–2005. With Charlotte Danielson, she has co-authored, _A Collection of Performance Tasks and Rubrics: Primary School Mathematics._

### Resources


The *Bridges in Mathematics* curriculum is available from the Math Learning Center in Salem, Oregon. For more information, including teacher comments, samples, correlations to standards, and resource guides, visit [http://www.mathlearningcenter.org](http://www.mathlearningcenter.org). This site also has links to professional development workshops and many other products and materials.

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**The Connect Archives**

Hundreds of articles on exemplary science and math education are included in the *Connect* archives, online at [http://www.synergylearning.org](http://www.synergylearning.org). This service requires no registration and is provided free to educators. We’ve listed several here:

- “Motion, Time, Angles and Beauty,” by Margaret Dale Barrand, November/December 2000.
- “When 5 and 6 Year Olds Invent their Own Systems,” by Annette Raphel, January/February 2002.
This issue of *Connect* challenges educators at all levels to think hard about how to preserve experiential, hands-on, inquiry-based investigations in the face of NCLB assessment practices that are more in line with “drill-and-kill” instruction. In too many classrooms instructional and assessment practices that have proven over and over to be the most supportive to student learning have been abandoned.

I believe one of the most damaging effects of these changes is that many students no longer have true ownership of what they know because they haven’t processed or experienced the content in ways that enable them to apply it in different contexts. Thus, when a test confronts them with a particular situation, they often resort to guessing or choosing a formula to plug into the problem, rather than having a personal arsenal of strategies they’ve used before in varied situations.

Fortunately, there are teachers, schools, programs, and districts that have succeeded in maintaining best practices in the face of this pressure, most often through strong leadership, effective professional development, and/or high levels of creativity. Instructional practices that enable children to engage in realistic, personally meaningful learning experiences contribute to students’ truly owning their learning.

From an intrinsic source

How does ownership evolve? I believe the roots of ownership stretch back to the earliest years of schooling, when young children so readily engage in learning. Perceptive early childhood teachers nurture and witness the beginnings of ownership every day as children immerse themselves in experiential, hands-on, inquiry-based investigations. These teachers know that child-initiated experiences have the most meaning and the greatest impact because they come from inside the child rather than from an external source. In well-planned, purposeful learning environments where teachers are skilled observers, children begin to develop ownership of what they know and can do by having multiple and varied opportunities to apply content knowledge and inquiry processes.

Let’s consider some examples of four- and five-year-olds developing ownership of content and inquiry processes in some important areas of math and science.

**NUMBER AND QUANTITY**

- As the teacher goes around the circle tapping each head, Hattie joins in as the whole group counts the people at morning meeting. At the end, she exclaims, “I didn’t know we had 17 people here!” This teacher knows that counting classmates is more meaningful to young children that counting arbitrary objects such as beans or plastic counters. Hattie reveals a developing sense of quantity. She knows that 17 is not just a number that comes after 16, but that it represents a collection of important people in her life.

- Kenny makes a design with Pattern Blocks.
Blocks. He puts an orange square on 3 sides of a yellow hexagon, looks at what he has done, then takes 3 more orange squares all at once, and adds them to the 3 remaining sides.

Kenny’s teacher knows the power of Pattern Blocks to help children create highly organized designs that have symmetry and include patterns. As he represents his mathematical thinking through creating a design, Kenny demonstrates both one-to-one correspondence (by matching one orange square to each side of the hexagon) and subatizing (recognizing an amount without having to count).

• Barbara is drawing with markers. She is holding 4 markers in her left hand and drawing with the fifth one with her right hand. She glances over at her neighbor who is drawing with 1 marker and has 3 more markers right beside her piece of paper. She states softly, “I have more markers.”

Some teachers might limit their interpretation of this observation as a social issue, but Barbara’s teacher homes in on the considerable math skill demonstrated in this everyday occurrence. Barbara first adds up the markers in her hands, then adds up her friend’s markers, and then compares resulting quantities.

GEOMETRIC SHAPES

• During snack, Mike folds his napkin in different ways. He folds it once to make a rectangle. He folds the rectangle in half to make a small square. Then he unfolds first the square and then the rectangle and re-folds the napkin diagonally, creating a triangle.

In this observation, Mike demonstrates much more geometry knowledge than simply naming shapes. From a single square napkin, he creates, takes apart, and re-creates multiple shapes.

• A child is adding triangular blocks to the top edge of a block building. She uses all of the triangles around her and asks Lori, “Can you pass me some more triangles?” Lori hands the child one of the tall, skinny triangles. The child rejects it, saying, “Not that kind, the other kind.” Lori puts the first triangle back on the shelf and hands the child one of the small equilateral triangle blocks.

Lori’s teacher notes that she knows about different kinds of triangles and solves a problem by thinking flexibly.

• Paul and three other children are helping the teacher label circular things in the classroom with round sticker dots. He points to the clock on the wall, the wastebasket, the holes on the pencil sharpener, and a plate on a shelf.

This teacher takes advantage of children’s acute observation skills and their strong desire to sort and classify things in their environment. Paul makes connections among multiple circular shapes in the environment, thus demonstrating a firm grasp on the concept of a circle.

LIVING THINGS

• Levalle spots some ants on the ground while playing outside. He gets down on his knees so his face is very near the ants. After watching for a few minutes, he crawls away on all fours saying, “Watch out, here comes a giant ant!”

Levalle is not just being silly. He has observed and internalized the anatomy and motions of ants and then communicates what he has learned through dramatization.

• Olivia cradles a baby doll in her arms and holds a cylindrical block up to its mouth as if giving it a bottle. After a while, she puts the block aside, holds
the baby over her shoulder, and pats its back. After several pats, she makes a burping sound, and returns to feeding the baby.

As adults, we often take children’s pretend play for granted, but in this scene, Olivia demonstrates some important understandings about infants—they eat differently than older people, they are dependent on other people to feed them, and it is important to help babies burp!

- Ian draws a large tree-like form on a piece of paper. He adds squiggly lines coming out of the bottom. When asked about the lines, he responds simply, “little roots.”

Not only does Ian make a representation of a living plant, he includes parts of the tree that are usually underground and therefore, not visible. Hopefully, Ian’s teacher will try to find out how he gained this knowledge.

EARTH AND SPACE

- Winona is picking up rocks on the playground. She examines each one, puts some in her pocket, and returns others to the ground. When asked how she decides which ones to keep, she says, “I only want the ones with sparkles.”

Natural objects are much harder to sort and classify than commercial sorting materials such as plastic teddy bears. The different attributes of rocks are less obvious, so it is quite impressive that Winona observes, sorts, and classifies them.

- After watching the teacher blow bubbles from a plastic wand for several minutes, Roberto asks to try. The first few times, he blows hard and fast. No bubbles come out of the wand; he frowns. He watches the teacher some more and tries again. He blows softly and slowly. Many bubbles float into the air; he grins from ear to ear!

Roberto observes and then experiments with different ways to blow air to produce bubbles. He uses a specialized piece of equipment (the bubble wand) and adjusts his own breath to achieve the desired results.

- On field trip day, Tanika enters the classroom looking very sad. When asked about the frown on her face, she responds, “I saw the clouds. It’s going to rain. We can’t go to the farm today.”

In the busy life of a teacher, it might be easy to miss the scientific connections Tanika weaves together. She observes the weather, makes a prediction based on her observations, and then draws a conclusion.

Reading the signals

In all of these examples, young children are demonstrating a budding ownership of mathematical and scientific knowledge and inquiry skills in ways that could not be assessed on standardized tests. Perceptive teachers see these demonstrations and translate them into future instructional steps that will deepen and broaden children’s knowledge and understandings.

Effective teachers of young children expose their students to knowledge, skills, and behaviors. They provide many engaging opportunities for children to independently apply what they are learning, and then watch and listen very carefully. This is how teachers know which children need more attention to certain concepts and which children are ready to extend their learning further. Children applying knowledge, skills, and concepts independently signal to teachers that they are taking ownership of their learning.
The Power to Make Predictions

by Julie King

Using a simple activity that children love to do, draw stars, Julie King presents questions and gentle guidance that take the investigation to a sophisticated level. This article was first published in Connect in March of 1990.

In the last few years the study of patterns has become a distinct topic in the mathematics curriculum, from counting to algebra. Stringing beads, clapping out rhythms, making designs with Pattern Blocks, and studying symmetry have gained the status of legitimate mathematical activities. Many teachers wonder why. What have these things to do with math? Will the ability to recognize or construct geometric patterns be helpful to children?

“Yes,” the textbooks say. But unless you have experienced the excitement of exploring patterns yourself and discovering some of the remarkable interconnections and relationships which exist, it may be hard to see how. To get a sense of where patterns fit in, we will take a single kind of pattern and examine it in many ways: how it can be described and produced, where it is found, what happens if you extend it, what other kinds of patterns it resembles, and so on.

Let’s consider a star

Children learn very early to draw five-pointed stars. Make five strokes; don’t lift your pencil; come back to the beginning. “Look, I drew a star!” The stars have five points. Some are “perfect.” The perfect stars have identical points in a circle, equally spaced. If you turn one part way around you see the same star again. This is called symmetry (five-fold rotational or radial symmetry).

Young children can be happy for a long time just drawing stars. A bulletin-board-sized piece of paper is a wonderful invitation. After the impulse to make those five motions over and over has been satisfied, children may begin to experiment with other methods. Can I draw a star backward? If I start at the top of the right instead of the left, will it look the same? What if I started inside, with the pentagon? Is there another way?

To the disappointment of some children, real stars don’t look like the stars they draw, but there are plenty of things which do: starfish, star grass flowers (and many other kinds), starfruit slices. . . . If you’re investigating stars with a class, start a collection of objects with star patterns. Not many of the natural items in your collection will be perfect stars. The lines will be curved or the points not quite the same size. But they are all star-like. They all have something in common. It’s the five-fold symmetry we mentioned. Turn each a fifth of the way around, and it will look the same as when you started. If you look for other things which have this star-like quality, you will find apples (sliced across), sand dollars, and strawberry blossoms.

Children may notice that some radially symmetric things have more than five sections, or points. There are stars with six points: snowflakes, the Star of David, a star made with one yellow Pattern Block and five green ones, the star on a Chinese checkers board. You can collect six-pointed stars, too, and cut out some snowflakes.

Drawing six-pointed stars

Can we draw a six-pointed star in the same way we can draw a five-pointed star, without lifting pencil from paper? Notice
that if you mark the points first, the pattern for drawing the five-pointed star was to skip a point each time, going to the second point.

Skipping to the second point doesn’t work for the six-pointed star. Could we draw it by skipping to the third or fourth point each time? Try it.

The answer appears to be no. We can draw a six-pointed star easily in two steps, lifting the pencil once, but not in one step. New questions pop up. Could we have drawn our five-pointed star by skipping to the third point instead of to the second? Try it.

Is the five-pointed star the only one which can be drawn without lifting the pencil? What about one with seven points?

Is there more than one way to do it? (In fact, there are two ways to draw a five-pointed star, and four ways to draw a seven-pointed start with one continuous line.) Do both five-pointed stars look the same? (Are they congruent?) How about seven-pointed stars?

**Other forms of star patterns**

A more physical way to approach star-making is to stand with people in a circle and throw a beanbag around instead of drawing lines. Skip over to the second person each time. If everyone gets a turn and the beanbag comes back to the starter, you have traced a star in the air. Try skipping to the third person, then the fourth, etc. To see the stars as they are created, substitute a ball of yarn for the beanbag and let it unwind as it is thrown, each thrower holding on to the yarn.

Another exciting means of exploring the same idea is to hammer a circle of round-headed brass nails into a piece of plywood, tie a colored thread or piece of yarn to one, and wrap the thread around the nails, skipping to the second nail each time. Use another color to test skipping to the third nail, and another for skipping to the fourth, and soon you will have both the answer and a lovely string design.

**Organizing discoveries**

The variations can get a bit confusing unless we stand back, take a breather, and try to organize our discoveries somehow. Perhaps there is a pattern here. We hope so, or all this star-drawing will have no end. So far we have found that stars with five and seven points can be drawn without lifting the pencil, but stars with six points cannot, no matter how many points are skipped.
Could it be that odd-numbered stars can always be drawn this way and even-numbered stars cannot? To look at our work more systematically we will number the points, 0 being the starting point. To test this conjecture we will also try drawing eight-pointed stars.

Then we can make a table of the successful and unsuccessful tries.

<table>
<thead>
<tr>
<th>SUCCESSFUL</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Points in star:</td>
<td>5  5  7  7  7  8  8</td>
</tr>
<tr>
<td>Number of first point Drawn to:</td>
<td>2  3  2  3  4  3  5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UNSUCCESSFUL</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Points in star:</td>
<td>6  6  8  8  8</td>
</tr>
<tr>
<td>Number of first point Drawn to:</td>
<td>2  3  2  4  6</td>
</tr>
</tbody>
</table>

Now indeed, some patterns begin to emerge. Our odd and even guess will have to go, since some eight-pointed stars can be drawn. But look! In the “unsuccessful” list the first four numbers on the bottom are divisors of the numbers above them. Unfortunately, the last entry does not follow this pattern—another good idea demolished. However, 8 and 6 are both divisible by 2. No pair of numbers in the “successful” list has a common divisor, but all in the “unsuccessful” list do. Perhaps the secret is that we will succeed only if the number of points in the star and the number of the first point you go to do not have a common factor.

We haven’t seen all there is to see by any means, but we’ve come a long way. We began by simply drawing stars, then looked for stars and star-like things around us. We learned about rotational symmetry and then returned to search for patterns in different kinds of stars. We ended up talking about the numbers and divisibility.

We’re on the verge of being able to make some predictions. I can say now, without having tried it, that I will be able to draw a twelve-pointed star without lifting my pencil if I go to the fifth point each time. Do you agree?

This is what patterns can do—help us to see order in shapes and numbers and the world around us. They suggest new ways to explore it. They give us the power to make predictions. They enable us to join our knowledge of number and shape.

Don’t be afraid to start such an exploration in your classroom, even though you don’t know exactly where it will lead. Some of the most memorable learning experiences are those in which teacher and student explore together.

Julie King taught for many years at Antioch-New England Graduate School in Keene, New Hampshire. She has authored several books on teaching mathematics, including, Exploring Everyday Math (1993), co-authored with Maja Apelman.
As science has become more dependent on magnification and sophisticated chemical and physical analysis of the natural world, more of our conclusions and explanations of how things work must be accepted based on the authority of others. Much scientific knowledge has become abstract. A danger in teaching science as a body of knowledge is that such acceptance of what others have figured out encourages good minds of all ages to ignore their own observations and intuition.

We all make observations that don’t jibe with currently accepted knowledge. For instance, both the sun and the moon appear to rise in the east and set in the west. So they both appear to orbit the Earth, but among the first things we teach about the solar system is to make the point that only the moon orbits the Earth. Children, who are often very literal, may struggle with counterintuitive ideas or simply ignore them. In one of my literal periods at age four or five I remember being disappointed when I realized that it could rain on Sun-day.

Many ancient explanations are based on non-technical, but careful, observations. These phenomena are still observable and indeed are part of the first knowledge gathered by young people. A number of these observations can be used as the basis for learning how science works.

Imposed limits on learning

Children are inherently curious. What they learn about their world comes from their own perceptions and it is combined with information added by others. The others are mostly adults who, from the child’s perspective, also provide a variety of rewards and punishments. For the child, it becomes important to agree with the authoritative adults, parents and caregivers, and later, teachers in school. Students often explore to find patterns, but stop searching when their new explanation seems to please an adult. Many times the adult explanation does not satisfy the young person’s curiosity nor provide a satisfactory end to the search. This can be an early source of misconceptions.

In early schooling, students are taught the prevailing language and its communication patterns. The symbols—letters and numerals—are precise. Letters are combined to make words with correct spellings and they are strung together in appropriate groupings to convey limited meanings. Numerals are manipulated to gain specific results. And by this regimentation primary grade students are persuaded to accept adult directions and explanations and to ignore other possibilities that may occur to them. This results in acceptance, without question, of adult products such as print and other media.

Schooling in science

If science is presented in primary grades as an exploratory activity, students should be allowed to arrive at their own conclusions. However, what often happens is that students mess around with the provided materials long enough to figure out what the
teacher wants them to “learn” from the activity. All too often the problem posed comes from the teacher, and would not have occurred to the students. And so curiosity and science are separated for most students by the time they reach intermediate grades and middle school.

The incoming middle school student usually accepts what is in the science text, because it is in the book, not because it makes sense. Too often the texts and lessons from earlier grades provide isolated facts to be memorized. These specific facts need to be associated with the concepts they support to foster understanding of how the natural world works. In order to teach how science is done and to create more scientists and engineers, students’ schooling needs to foster observation, curiosity, and to require sufficient evidence from authorities for conceptual learning.

It became apparent to me years ago while teaching junior high school science that using previously accepted explanations of natural phenomena can provide a useful review function. The ancient explanations were based on observations available to all because they required neither visual magnification, nor molecular analysis.

No air

Early in my teaching career, as a brief review before the unit test on air, I proposed to seventh graders that if I had come from an ancient time I would not understand their conversation about air. The text chapter was about air and its components. In class demonstrations we had chemically generated oxygen, carbon dioxide and hydrogen as described in our textbook. (Note: These demonstrations are no longer considered safe in a classroom without a ventilating hood.) So the unit test was to be on the chemical components and physical properties of air that they had studied.

To be consistent in my conversation with the students, I adopted the old four-element explanation, but I mentioned only earth, fire and water. My premise to the students was that I didn’t understand how they thought there was something that I couldn’t see, smell, taste or feel in the empty spaces between us. My rebuttal to each of their explanations was based on this premise or was composed of a lie so bold that they should have had the information to refute it.

To my surprise, and joy, the students became seriously engaged in trying to prove that I was wrong. They begged for time the next day to demonstrate to me that there is air. And the following day they brought in materials to demonstrate the force of air movement by various means, but with our equipment had difficulty making that case that air had mass. Later I learned from teachers and parents that they had asked many others for help in making their case.

The nature of science

The Flat Earth is another example of an old concept that I have used. Intuitively, our own observations support a flat rather than a spherical earth. The earliest recorded explanations for the earth included water on all edges and pillars to hold up the sky. Such descriptions fit our own early, less precise observations. Travel to other land masses and better observations of stellar movements make such explanations less acceptable. There are two sources available to demonstrate how this might work.

The first source is designed to help students decide what makes information acceptable in science. It was assembled to assist high school biology teachers develop student skills for sorting science from alternative explanations that purport to be science, such as creationism. ENSIweb is an online resource for teachers that contains lesson plans and resources for teaching about the nature of science and about evolution. (ENSI was a series of NSF supported institutes called the Evolution and Nature of Science Institutes.) The Web site was developed and is tended by an ENSI alum after the institutes (1989–1997) were completed. For the first time we have a common format for lessons from many teachers working in different institute groups. We found that many of the nature of science lessons were suitable for younger students. These lesson plans can be found at http://www.indiana.edu/~ensiweb/.
Web lesson

The Flat Earth lesson on ENSIweb asks students, based on their own information, to demonstrate that the Earth is not flat. In the process they sort their own observations from secondary sources. Secondary sources for them include pictures from space that are usually printed on flat surfaces. They also recheck their own observations to determine which do and don’t make the case for a non-flat Earth. For instance, the Earth’s shadow on the moon could be from a flat disk that is round but not spherical. As it turns out most students have not observed a ship appearing or disappearing on the horizon, and so personally have no valid primary observation of a non-flat Earth.

The final part of this lesson encourages students to develop a short list of terms that characterize science. These can vary depending on the class, but must include such things as repeatable and/or testable, natural and tentative. Use of such lists can help students and the class judge the reasonableness of news stories and other public information.

Another concept from this lesson is that science explanations must change when newer and more complete evidence requires a newer and better explanation of natural phenomena. So while the Earth was once thought to be flat, we now know that it is spherical. The early “Flat Earthers” were using all of the available information. The current “Flat Earthers” are ignoring valid available observations.

Video of Flat Earth

In Search of the Edge was produced as a “fake science” video in defense of the current Flat Earth explanation: that it is a disk-shaped earth with the North Pole in the center, an ice wall on the outer edge. The ice wall is compatible with observations of Antarctica. The video format is similar to the one used in science programs such as Nova. “Experts” are interviewed to explain the principles of the Flat Earth. The human interest element of the program is the story of Andrea Barnes who is intent on traveling to the ice wall to prove that the Earth is flat, contrary to what she was forced to learn in school. The

Flat Earth “experts” and their explanations are humorous to those who understand the tongue-in-cheek presentations.

While the video is a wonderful spoof, a careful debrief is essential for an audience of people of any age who take what they see on television as fact. The unintended consequences of an incomplete debrief may be selling the Flat Earth concept, a lesson I learned while teaching a college general education science class a few years ago.

A full debrief should include discussion of the evidence provided in the story by the “experts” and the inferred credentials of the “experts.” Discussion should get to a listing of qualifications for acceptable authorities such as profession or position appropriate to “expertise.” Further discussion could provide authenticity-screening criteria for Internet, TV and other media presentations.

In the “No Child Left Behind” era of more testing, we often only demonstrate “learning” of factoids rather than understanding of concepts. In other words, it is now more acceptable to teach about what scientists have figured out than to teach how science is done and why it is fun.

Skeptical curiosity and insistence on evidence are essential to the process of science. Young people who are more dependent on media need to develop skills for being skeptical of all information sources. Giving students practice in assembling evidence for concepts they have accepted is a good review technique. Using examples from explanations of less sophisticated times has much potential. I have offered two examples here. More old concepts and explanations could be developed for science reviews. I’d be glad to hear about others that work.

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Planning for Understanding

by BOB COULTER

It’s no secret that recent accountability measures have presented challenges for teachers seeking to maintain rich and deep learning environments for their students. Those who do manage to achieve this are often put on the defensive, expected to justify why they aren’t “following the plan.” On the theory that the best defense is a good offense, planning a strong unit and being able to affirm why your curriculum is a better choice for students can head off the nay-sayers. To that end, online planning tools such as the Collaborative Curriculum Design Tool can be a valuable part of your technology tool belt. This online resource, offered by the Harvard Graduate School of Education, allows you (and colleagues, if you wish) to develop and share plans for a strong learning environment that is based in whatever academic standards you are accountable for.

After completing a free registration (at http://learnweb.harvard.edu/ccdt), you can begin creating a curriculum unit using either of two major curriculum frameworks: Teaching for Understanding or Dimensions of Understanding. The examples here use the former model since I’ve used that a number of times in planning units. Within the Teaching for Understanding model, you will be guided to articulate your plan using an online template. If you get stuck or need inspiration, help and examples are only a click away.

Throughlines provide the big, overarching topics that guide your curriculum planning such as, “What causes an ecosystem to change?” While they are usually too global to provide direct planning guidance, they can function as a metaphorical north star guiding the more detailed planning you will be doing. The substance of your planning follows in the later elements. Given the time constraints that all teachers face, using your throughlines can help in determining what activities are most relevant to keep and what you can let go of without taking away from your larger purposes.

Generative Topics are the areas of investigation that hook your students’ attention, inviting them to inquire, analyze, and reflect on. They are intrinsically engaging, and likely to sustain interest well beyond the time allocated in your curriculum. The trick here is to make the topic invitational. The same topic can be framed quite differently, drawing a different response from your students. For example, water chemistry will have only a limited appeal; investigating how water quality impacts organisms in your local pond or creek is more likely to engage and sustain interest.

Understanding Goals allow you to articulate what students should get out of their involvement in the unit. This is your chance to define publicly the learning benefit students will gain as a result of their participation. The key here is multifaceted understanding, not simply recitation. Students who understand ecosystems, for example, will be able to see how individual organisms fit into the ecosystem, understand roles such as producer, consumer, and decomposer, and evaluate the impact of various changes in an ecosystem on its inhabitants.

Note that underneath this understanding is a range of more specific bits of knowledge (such as the difference between being a producer, a consumer, or a decomposer). The difference is in the movement away from a bag full of isolated facts toward a larger, more intellectually robust conceptual network. For example, I worked with my fourth graders in the local community to develop a robust understanding of biomes, which they were then
able to transfer from the first-hand work we did in the temperate deciduous forest to other more distant biomes. While the specifics changed in terms of climate and species present, their conceptual understanding of biomes stood up and proved to be useful in new contexts.

Performances of Understanding provide opportunities for students to show what they know. More than just getting a good grade on a test, the Teaching for Understanding framework calls for a “flexible performance capability” that allows students to show what they have learned in an authentic context. For example, in a unit engaging students in studying optics, students could apply what they have learned by combining lenses to make a telescope.

More generally, the Teaching for Understanding framework suggests that students be able to display their knowledge, engage in focused inquiry, be aware of different domains of understanding, and be able to communicate their understanding to specific audiences. Collectively, this suite of skills goes well past the usual short answer, artificial response solicited by most standardized assessment tools. Obviously, not every learning opportunity in your classroom will build toward a major, culminating performance, but these opportunities should be pursued where possible, since they are motivating and provide an opportunity for students to integrate what they are learning. Practically speaking, being able to document and display students’ learning in this larger realm can inspire confidence in the quality of learning experiences.

Ongoing Assessment provides a way to document how students are building toward their performances of understanding. All too often, teachers new to more complex, project-oriented learning leave assessment to the end, and then when projects don’t meet their initial hopes, they write off the idea of complex learning either as something that their students couldn’t do, or even as a bad idea all together. Big constructions are made of small pieces, and your ability to assess how students are doing en route to their performances will go a long way in ensuring the success of the larger project. Armed with this knowledge, you can provide constructive feedback while there is still time for students to improve their performance, and where needed, alter the pacing or instruction you are providing.

In addition to these sections in the planning template, you can also articulate the technology resources you will use, and most important for the context of this issue’s theme, articulate the curriculum standards you are addressing. By crafting a well-articulated curriculum design that is grounded in relevant standards, your plans can stand more strongly and less defensively if you are challenged. More importantly, your plans will ensure that your students will have a meaningful learning experience.
Here are suggestions of a few books to encourage creativity, inquiry, observation, and attention to the process of learning and figuring things out. Some of them also show children engaged in everyday activities that use math, science or technology.

*What Do You Do with a Tail Like This?*, by Steve Jenkins and Robin Page (Houghton Mifflin Company, 2003), captures the imagination by revealing only parts of animals’ bodies (tails, ears, noses, feet, etc.), and asking readers what they might do with them. A format like this does at least two things simultaneously: first, it asks us to regard isolated parts which increases our focus and widens the capacity for noting diversity. Secondly, it stimulates creative thinking and offers readers a chance to internalize what they are seeing and learning about. What if I had a nose like a starry-nosed mole? Or an elephant? What if I could walk on the ceiling like a gecko? The exquisite illustrations are made of cut paper. Factual information on each animal follows the story.

*The Squiggle*, by Carole Lexa Schaefer (Crown Publishers, 1996), is a great example of creative thinking. A little girl walks at the end of the line of children. “I am last. No one else sees what I see on the sidewalk.” She finds a squiggly piece of string and imagines it into all manner of things, like the curve of a dragon’s body, the sky trail of fireworks, the edge of a storm cloud. Pierr Morgan’s calligraphic drawings, like the imagery of the text, reflect examples of Chinese culture. Lively and playful, this book inspires children ages five through eight to let their imaginations fly.

*Alexander, Who Used to be Rich Last Sunday*, by Judith Viorst (Atheneum, 1985), chronicles exactly what happened to the dollar Alexander was given by his grandparents a week ago. Part of the success of this book is the convincing child’s voice that tells the story, complete with details about the two older brothers who each receive their own dollars (and still have most of the money). This is a great accompaniment to studying currency for second through fourth grade, with references to coins, saving, spending, betting, and borrowing money. One could read it as a class while students practice subtracting cents from 100, or use a calculator to keep a running tally as Alexander spins (and spends) his tale of woe.

*The Button Box*, by Margarette S. Reid (Puffin Unicorn, 1990), shows a young boy playing with the buttons in his grandmother’s special box. Sorting, classifying, building patterns, and noticing similarities and differences are some of the concepts explored. Colored linoleum cuts by Sarah Chamberlain appear slightly dated, but still clearly and simply show a deeply interested child investigating a variety of styles and forms of buttons. This is a good book for beginning readers or to read aloud as a starting point for sorting activities with young students.

*Ten Mile Day*, by Mary Ann Fraser (Henry Holt and Company, 1993), is an example of a very natural integration of mathematics and history. This is the story of April 28, 1869, the Ten Mile Day, when the leaders of the Union Pacific and the Central Pacific Railroad crews wagered that they could each
be the first to lay ten miles of track in one day. With carefully researched illustrations and text that does not belittle the hardships and inequities of the effort, the author outlines events leading up to and comprising that day. Fighting between rival groups of Chinese workers, attacks from Natives who understood the consequences of the railway cutting across their homelands, fatigue, dehydration, and illnesses are mentioned as terrible conditions. But another focus is the magnitude of this effort. Many details are offered as to the size and number of materials, the timing of the event, and the distance covered. Also emphasized is the Herculean efforts of the workers, with names of some and references to sources that students can consult for more information. Fourth through sixth graders could use this as part of an integrated study. Teachers should not miss the opportunity to discuss from whose perspective the history is written and explore what it might look like from another’s perspective.

Chapter Books that are fictional can be interesting additions to studies of measurement, habitats, problem solving, and many other concepts. Charlotte’s Web could be used to explore animals’ roles in the ecosystem, for example. Stuart Little or The Borrowers series could be used as examples of scale. The Phantom Tollbooth, J.R.R. Tolkien’s The Ring Trilogy, and My Side of the Mountain are examples of literature that rely on maps and place. Arthur Ransom’s Swallows and Amazons series draws on navigation, mapping, codes, and problem-solving as it relates the adventures of four siblings adventuring on their own.

Remember the value of a conversation with your school or town librarian, who can provide suggestions of good literature that encompass whatever theme you are working on.
The Math Coach Field Guide: Charting Your Course, edited by Carolyn Felux and Paula Snowdy, is a valuable collection of narratives advising math support teachers, specialists, resource teachers and coaches. What are the most effective ways of helping elementary teachers in mathematics? Many years of experience back up the suggestions of these eleven authors. This book takes the place of sitting down and chatting with experts and is a useful guide for novices and longtime practitioners alike. 124 pages.

Math Matters: Grades K–8, Understanding the Math You Teach, by Suzanne H. Chapin and Art Johnson, is a comprehensive guide for all levels of elementary and middle school. Each of fourteen chapters in this second edition tackles a math topic (number sense, algebra, measurement, etc.) and introduces basic concepts, defines terms, and offers explanations that are clear and support confident teaching of that topic. Written for the busy educator, this is an excellent and easy to understand resource that can be used for quick reference questions as well as to fortify overarching ideas and understandings of the “big picture.” Web resources are included. 348 pages.


You’re Smarter Than You Think: A Kid’s Guide to Multiple Intelligences, by Thomas Armstrong, is written directly to children, explaining Gardner’s multiple intelligences. This book outlines eight different kinds of intelligences or, “smarts,” including word smart, music, logic, picture, body, people, self and nature smart. Each chapter explores what it means to be smart in one way, what to do if you’re not strong in that area, how to support it if it is a strength, and suggestions of activities that would be enjoyable or beneficial in that area. When these ways of teaching and learning are explored as a class, a respect and recognition of various ways of processing are emphasized. Children regard themselves, and others, with new esteem for talents and skills that might otherwise go unnoticed. 192 pages.


Teaching the Best Practice Way: Methods that Matter, K–12, by Harvey Daniels and Marilyn Bizar, is a collection of examples of educators who use authentic practices. In seven chapters the authors outline what they think are the building blocks of good instruction. These are described as: teaching as thinking, representing to learn, small group activities, classroom workshop, authentic experiences, reflective assessment, and integrative units. Different teachers are showcased and each writes a few pages...
about valuable teaching. The introduction addresses how these methods stand up to standardized tests. Written anecdotally, this book also provides examples of children’s work, sample activities, and suggestions for how to start. 343 pages.

**Black Ants and Buddhists**, by Mary Cowhey (see her article on page 23 of this issue), is a moving and funny book about one teacher’s adventures in teaching all subjects critically, with rich examples in math and science. Cowhey encourages her first- and second-grade students to question, to reason, to express and communicate. Through investigating questions of their own, community involvement, and social action, students learn both the basic academics and the greater lessons of being a human in the world. Simultaneously inspiring and challenging, this book is nothing short of a call to action. 244 pages.

*Teaching the Best Practice Way: Methods that Matter, K–12* ($24.00) and *Black Ants and Buddhists* ($18.00) are available from Stenhouse Publishers, PO Box 11020, Portland, ME 04104-7020. Call 800-988-9812, fax 800-833-9164, online at [http://www.stenhouse.com](http://www.stenhouse.com).

[http://www.nctm.org/focalpoints/](http://www.nctm.org/focalpoints/) is NCTM’s online publication describing focal points, the most important mathematical topics for each grade level. It comprises related ideas, concepts, skills, and procedures that form the foundation for understanding and lasting learning. From this page, the book is downloadable by chapters. NCTM relates the focal points to their previously published Standards.

[http://www.arborsci.com/Resource.htm](http://www.arborsci.com/Resource.htm) is the resource page of Arbor Scientific. It has lots of links to good sites such as the Exploratorium, NSTA, etc. Arbor Scientific itself also has a small but useful collection of science teacher publications and products in their catalog.

*Assessment for Learning*, by Paul Black, Dylan Wiliam and additional authors, explains their study of formative assessment as a tool to support positive progress in learning. The authors critique the effectiveness of on-going formative assessment and propose ways to improve upon its use in classrooms. Their research documents the value of this type of assessment as a continuous feedback loop for teacher and student. In this book, they argue for better implementation of formative assessment, especially to aid in ending the negative impacts of conventional, high stakes assessment on low-achieving students. The book introduces research and also provides action steps for schools. 135 pages.

While traveling to Mexico recently, I encountered many math challenges as I navigated an airport, checked flight schedules and converted pesos to dollars to find the price of a sombrero for my classroom birthday hat. I never needed to know, “Which array showed that the correct result of multiplying a number by 1 is the same as the number?” Education is assessment driven. A determination must be made as to whether the cart is being put before the horse if we allow instruction and curricula to be guided and developed by professional test writers. Do we do a disservice to children when academic pronouncements drive the development of classroom content without consideration and significant involvement of experienced educators who are actually responsible for the communication of this knowledge?

Isolated skills?

The educational pendulum, which has become powered by standardized tests, seems to be swinging away from the theory of teaching students the skills they will need in the real world to teaching students the information they will need to pass state and national tests. Educators know that teaching isolated skills is futile unless they are attached to something which has real meaning for the student. Yet standardized tests measure only a command of isolated skills. Teachers around the country are asking themselves, “How can we continue to make learning exciting, meaningful and fun, despite the pressure of annual high stakes tests?”

Recently my colleagues and I gathered around a computer, analyzing the results of our school’s latest standardized test. Comments such as, “He probably guessed to get that one right because I know he doesn’t understand perimeter very well,” or, “I’m surprised she missed that one. Problem solving is one of her strengths, so she must have misunderstood the question,” filled the room. One of my colleagues turned to me and said, “These are almost identical to the results we gathered the first couple of weeks of school.” Why does public education, which is already so desperately under-funded, spend so much money on expensive tests that we know do not always accurately measure what a child really knows and rarely tell us more than a good teacher discovers within the first few weeks of school? Knowledgeable teachers then must spend time to evaluate which students have accurate test results and which do not.

Formative assessment

Skilled instructors quickly learn each student’s strengths and weaknesses through informal evaluation that occurs daily. Formative assessments such as oral questioning, observing, analyzing written work, listening to student discussions and even considering a student’s self-evaluation, are used to determine which students need additional instruction for specific skills. Questions asked in class, to which students either
respond orally or with a visual “thumbs up/down” or similar technique, allow the teacher to make immediate changes in teaching for some or all students.

The teacher’s observation of a child as she explains the solution to a subtraction problem using Base Ten Blocks gives the teacher information about the level and complexity of the child’s reasoning. This observation is immediately usable and infinitely more valuable than a single numerical score from a standardized test. It allows the teacher to understand the individual child’s grasp of the concept and to tailor future instruction to the needs of each student.

Once a teacher feels confident that her students have the basic skills to solve more complex problems, she can give students projects that focus on many different skills at the same time and incorporate interdisciplinary instruction. For example, after reading a book in which a party was a central event, the teacher may ask students to work in small groups to figure out information for a real party that the class needs to plan:

• If each student can invite two guests, how many people will be at the party? How many guests should we expect?
• What will we serve and what will be the size of each serving (in ounces, cups, pounds)?
• What type of container will best hold the food and how should we construct the container?
• When purchasing napkins and silverware, how many packages will we need of each?
• If each table seats eight, how many tables will we need?

These questions become important to children when they know they are planning an actual party to which real guests will be invited.

Listening to students

Student discussions provide another effective informal assessment the teacher can use as she or he circulates and listens to the thought processes of students while they work in a group to solve a problem such as:

• If a T-shirt manufacturer charges $0.10 per letter, how much will it cost to put your name on the shirt? How much would it cost to buy the letters for the whole class? What if the class had two dollars less than they needed?”

Again, this is consequential only if students are actually designing the shirts. Isn’t there something to be said for a student who decides that each student must come up with a nickname that is five letters (or less) to save money? Or a student who announces that the craft store she frequents usually has coupons for 50% off a purchase? It also provides natural exten-
sions for a student ready for additional challenges. Asking students to evaluate their own understanding is helpful to the child, as well as to the teacher. Rubrics or questions that require students to evaluate themselves or their group provide an opportunity for reflection and additional learning.

Projects such as these use scope and sequence to help teachers provide a foundation and then extend learning. They permit students at many different levels of achievement and ability to learn simultaneously at their own "level" and from each other. They introduce children to the real world of teamwork in problem solving.

However, inadequate time has impacted this method of instruction. Teachers feel more pressure to cover material that will be included on state and national assessments prior to the scheduled testing window. Less time is devoted to or even available for "real teaching" or real thinking. To prepare for standardized assessments, some teachers try to assess in ways similar (or identical) to the actual test, rather than using methods of authentic assessment, such as those described above, in which student learning is an integral part of the assessment process. Accountability for test results has caused some teachers to spend inordinate amounts of time teaching rote memorization of information, using only the identical vocabulary and assessing only the information that will be tested.

State assessments

There are so many more important ideas to learn besides those tested in such a sterile way. What happened to the importance of Bloom’s taxonomy? Why do test developers see more importance in a question that asks a child, “Which of these shapes is repeated in the drawing of a rug?” than an opportunity which allows students to synthesize or evaluate information, such as, “Invent a 3-D container that can hold 16 ounces of popcorn.” or, “Choose two ways to graph favorite ice cream flavors in your classroom and explain which graph best represents the results”? In the weeks prior to state assessments, one might overhear teachers commenting to each other such things as, “We’re not ready for it, but we’ve got to squeeze in adding fractions so they’ve at least seen them before the test.” So much for scope and sequence. In the classroom, one might hear teachers commenting to students, “No, Sydney, we don’t have time for you to share how you can make a light bulb light with only a paper clip and battery! And no, Ana, we don’t have time for you to share a copy of money printed in the 1700’s that your parents came across in their attic! We haven’t learned how to calculate area, and ‘The Test’ is next week!”

So much for, “teaching the whole child.” Sometimes teachers are forced to make poor decisions in scope and sequence in order to fit material in before the test. Sometimes teachers feel they do not have time to relate to their students as people. Learning is so rushed, educators may feel pressure to take out the activities that bond students to teachers and let kids be kids.

If educators know that active learning is the foundation for understanding, shouldn’t the same be true for assessment? There may be a need for some sort of standardized test, but the importance of it should be equal to the weight of the information it provides. Proper preparation of teachers and adequate professional development should be much more important than the results of a multiple choice test. Not only are the tests expensive and inadequate, they are time consuming and they diminish the real learning that should be occurring in the classrooms. Albert Einstein said, “Everything that can be counted does not necessarily count, everything that counts can not necessarily be counted.” Although these standardized tests certainly have some value, they cannot represent the totality of the educational experience. An emphasis that is focused only on objective criteria ignores the fundamental importance of the learning experience.

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I’ve been thinking about this question of how teachers can meet the challenge of raising standardized test scores while continuing to engage students with authentic, inquiry-based, hands-on learning. This question reminds me of how I first taught science ten years ago. We weren’t preoccupied with standards back then. When I was hired, I asked what I should teach and was told, “Reading, writing, math...you know, first grade.” I had no textbooks. All the other teachers kept monarch caterpillars in their classrooms, so I went out to a field and found some myself. I brought my class for walks in the local swamp to observe seasonal changes. In short, I did not have a standards-based science curriculum. I was clueless and winging it.

The yogurt cup experiment

I used a lot of old yogurt cups in the classroom to pass out math manipulatives like beans and dice. One winter day Ana Mari filled up a yogurt cup with water and brought it out for recess. She forgot the cup on the stoop outside the classroom. Ana Mari found the cup the next day and discovered it no longer contained water but ice. When the children came in from recess, they crowded around her, jostling to see and touch the cup, like this was a miracle. I thought that was weird. I mean, by the time you’re six, you’ve seen ice cubes, and in Massachusetts, you’ve seen plenty of frozen puddles. I didn’t get the mystery.

Ana Mari asked me if she could share. I said sure. The audience could hardly contain its excitement. She rose with confidence, told the story of the yogurt cup being left out and then brought in. For her finale, she dumped the yogurt cup and gave it a dramatic whack. Voila! The wet round ice slid onto the rug, while the children all oohed and wowed. “How’d you make it do that?” Papo asked.

Ana Mari said, “I just left it on the step yesterday. I got this today!” More wows. This was like leaving your tooth under the pillow for the Tooth Fairy. I thought to myself could they not know that the cold temperature turned the water to ice? I was waiting for some smart aleck to contradict Ana Mari, but instead, Carmen asked if she could have a yogurt cup. I said sure. In the next minute, every other child asked too.

This went on for days. Every time I’d pick them up from recess, they’d be lined up, carrying these old yogurt cups in their mitten hands, asking if they could share. We put names on the cups, to reduce fighting, and began to keep a chart of our observations. We’d go around the circle and they’d all dump their cups on the rug.

Students marveled at how a cup of water left outside overnight resulted in a block of ice the next morning.
was nixed because sometimes the dumped cups revealed a piece of ice and a splash of water. They began using the word “freeze” to describe the change.

The next hypothesis was that the sun was freezing the water. This hypothesis was bolstered by Friday’s evidence that the water was not frozen on the cloudy day. I was tempted to just tell them that water freezes at 32 degrees Fahrenheit and move on. Something told me not to rush it. Since I wasn’t required to teach about ice, I didn’t feel any pressure to “cover it.” The experiment continued for another week of soggy mittens and soaked rug. I put some thermometers out as bait. When I observed Paulo, a selective mute, covertly trying to break one, I pulled him aside and showed him how to use it. He watched me and said nothing. By the end of the second week, all of my first graders knew how to use thermometers and had figured out that it was the cold temperature that made their water freeze.

Connecting to the community

Gretel told the yogurt cup story to her mother, who knew a chemist who could make ice cream with liquid nitrogen. She invited him to visit our class. He wore a white lab coat, goggles, and very large safety gloves. He froze lettuce leaves and balloons. There was lots of fog tumbling off the table. I took photos; my students wrote captions for the photos to make a class book. Later, states of matter became part of the second-grade science curriculum. Gretel moved out of the district about a month after the chemist’s visit, but all these years later, he still comes to make ice cream with liquid nitrogen.

I recently talked to one of my former “yogurt cup experiment” students. She recalled her memories of first grade: hatching chicks, getting old shopping carts and tires out of the swamp, learning about the civil rights movement, and liquid nitrogen. “When I was in middle school, my science teacher asked us if we knew what liquid nitrogen was. No one else knew, but I raised my hand and told them I learned how to make ice cream with liquid nitrogen when I was in the first grade. I felt proud.”

I look back at the yogurt cup experiment with a mix of humility, satisfaction and amusement. Then I think about standards and testing. Today I am teaching science using a standards-based science kit on states of matter that my district purchased for about $500.00. The science curriculum committee recommended the kits over science textbooks, which “covered” a curriculum a mile wide and an inch deep.

At the end of one lesson, the children watched me fill an ice cube tray with water and predicted it would be full of ice cubes the next day if I put it in the freezer. In the next uninspired lesson, I gave each pair an ice cube in a Ziploc bag and we had an ice-cube-melting race. I followed the script. They completed the worksheet.

Will they remember this activity in fifth grade when they take their first standardized science test? Probably not. How about in tenth grade, when passing a high stakes standardized test in science and other subjects will determine whether or not they get a high school diploma? Definitely not. Will the standards-based science kit lesson turn them on to science? Suddenly the yogurt cup experiment doesn’t seem so silly.

I appreciate the guidance the standards provide in articulating the big ideas I
should teach. I teach child-centered, inquiry-oriented science based on the standards but not because I think it will raise test scores. My teaching does no harm to test scores, but I don’t really care whether it boosts them. I am more impressed by a kid who shows empathy for a baby chick, or walks to school to reduce carbon emissions, or writes to the mayor to ask why an abandoned car lot can’t be made into a forest, than I am by a kid who scores at the advanced level. Ultimately, our society needs creative problem solvers, empathetic doctors, and ethical researchers.

Authenticity is key

So what do I do? I teach the required curriculum from the expensive science kit, but mostly I look for authentic connections. In a unit on simple machines, that means inviting in an old Puerto Rican locksmith who explains how keys are all about wedges. When a fist fight breaks out at recess about whether to save the trees or the tent caterpillars, we invite in a Buddhist scholar for a lesson on interdependence and email an entomologist in the Galapagos Islands with a list of questions like, “Would tent caterpillars be such pests if humans didn’t cut down so many trees?” This year I began the unit on states of matter with a field trip to Snow Farm, home of the New England Crafts Program, where we met a glassblower and a welder and watched them transform their materials into whimsical chickens and colorful fish and birds. And yes, I still leave out yogurt cups and keep my eyes peeled for soggy mittens.

Mary Cowhey teaches second grade at Jackson Street School in Northampton, Massachusetts. She is the author of Black Ants and Buddhists: Thinking Critically and Teaching Differently in the Primary Grades (Stenhouse Publishers, 2006) from which some elements of this article were drawn. She has received numerous awards for her teaching, including a Milken National Educator Award and an Anti-Defamation League World of Difference Award.
“We need significantly higher investment in innovation throughout society…” writes Thomas Homer-Dixon about humankind’s need to invent in order to cope with limited resources in the future (New York Times, 11/29/06).

A new report on K–8 science supports innovation in many forms and may cause us to rethink how we approach teaching science. Taking Science to School: Learning and Teaching Science in Grades K–8 (National Research Council, National Academies Press, 2006) provides multiple new ideas about instruction and definitions of proficiency in science. Research, reviewed in this report, discredits the commonly held belief that children think only in concrete and relatively simplistic ways. The report also contains studies of several curriculum strands. The best may be: the study of matter. This strand provides immediately useful material for curriculum and content discussions among teachers.

Taking Science to School, argues that we are still chopping science into confusing pieces. “Science education as currently structured, “it states, “does not leverage the knowledge and capabilities students bring to the classroom.” This report proposes specific changes that can help us focus learning in classrooms in order for our students to become the innovators society needs!