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How much easier it would be, how much more learning would occur, and how much time we would save if all students brought the same background knowledge and skills to what they are learning? This issue of Science and Children employs the Next Generation Science Standards (NGSS) to show the variety of ways in which you can use an instructional sequence that supports valid learning.

Image provided by Think Stock

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Look for the sciLINKs icon throughout the issue for web links to accurate, age-appropriate content and pedagogy.

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Science & Children articles from September 2004 to present are indexed in a searchable archive at www.nsta.org/elementaryschool.

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Summer 2015 3
Identifying a Progression of Learning

A sequence works in a way a collection never can. —George Murray

I’m sure you have had an experience similar to this one: I was beginning an investigation involving the states of matter and began to elicit prior understanding from my students. There were students in my class who were far beyond an introductory level—they could clearly explain and provide examples of each state, explain how a substance could change states, and accurately answer any question posed by other students. On the other end of the spectrum, there were students who had difficulty identifying the state of materials we were working with. I discovered that the main factor was the experiences students had with previous teachers. There had not been a specified progression of learning determined for our school system. We were all using the same textual material, but that did not necessarily mean that teachers were providing instruction to support understanding of specific core ideas and eliminating others at the appropriate grade level. How much easier it would be, how much more learning would occur, and how much time we would save if all students brought the same background knowledge and skills to what they are learning!

But, how do we accomplish an instructional sequence that supports a valid learning progression and can be followed by our learning community? The Next Generation Science Standards (NGSS) provides information to support the development of learning progressions based on research. Even if your state has not adopted and your schools are not using NGSS, the research behind the placement of disciplinary core ideas (DCIs), science and engineering practices (SEPs), crosscutting concepts (CCs), and student outcomes shown in the performance expectations is provided as a valid learning progression leading to the development of abilities and core ideas.

You may have missed what NGSS has to offer. The first place to look is at the beginning of each grade level set of standards. This storyline gives you a good overview of what students should be dealing with at grade level. Next, look at each standards page. Following each of the performance expectations you will find a clarification statement. This statement provides possible information that might be included as well as what should not be assessed. At the bottom of the foundations box, you will find articulation of the DCIs across grade levels, beginning with kindergarten and moving through grade 5.

The NGSS Appendixes also provide valuable learning progression information in DCIs, SEPs, CCs, and Nature of Science. You’ll find this in Appendix E, Disciplinary Core Ideas Progressions; Appendix F, Science and Engineering Practices; Appendix G, Crosscutting Concepts; and Appendix H, Understanding the Scientific Enterprise.

The NGSS might be the perfect tool for all of us to use in establishing a science learning progression. Of course, in any learning consideration we make, the needs of our specific student population takes highest priority in our deliberations.

Reference
We are seeking column submissions that present classroom-tested, novel, and engaging lessons for preK–5 students. They should include all of the components necessary for an engineering investigation to be completed and assessed, from design to implementation. Be sure to bring the voices of students and the teacher to the manuscript. In other words, focus on application of instruction that provides a peek into the classroom.

We are also interested in submissions that provide background information for the teacher that will support the teacher’s ability to construct his or her own engineering lessons. This might include suggestions as to where more information can be found concerning high-quality lessons, strategies for structuring lessons, resources that support teaching and learning, and strategies for use in evaluating lessons and materials.

Length: 2000 words.

The Blueprint

The Next Generation Science Standards (NGSS) integrate engineering into science education by raising engineering design to the level of scientific inquiry at all levels, from kindergarten to grade 12. The NGSS clearly shift our teaching to include technology and engineering. The NGSS explain engineering in this way: We use the term “engineering” in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems.

The NGSS explain that “The core idea of engineering design includes three component ideas:

A. Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success, and constraints or limits.

B. Designing solutions to engineering problems begins with generating a number of different possible solutions, then evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.

C. Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.

It is important to point out that these component ideas do not always follow in order, any more than do the “steps” of scientific inquiry. At any stage, a problem-solver can redefine the problem or generate new solutions to replace an idea that just isn’t working out” (NGSS Appendix I; www.nextgenscience.org/next-generation-science-standards).

Find manuscript guidelines and submission instructions at www.nsta.org/elementaryschool.

Submit manuscripts at http://mc.manuscriptcentral.com/nsta.

See our complete call for papers at www.nsta.org/sandccall.
THE NEXT GENERATION SCIENCE STANDARDS

Where are we now and what have we learned?

Stephen L. Pruitt

The Next Generation Science Standards (NGSS Lead States 2013) were released almost two years ago. Work tied to the NGSS, their adoption, and implementation continues to move forward around the country. I am most frequently asked about the pace of adoption by states, the implementation of the standards, and how the NGSS will be assessed. In this article, I will discuss where we are now and what I have learned during the process so far. As we implement the NGSS, it is important to remember that education is a journey, not a destination.

Where are we now?

As of April, 12 states and the District of Columbia—encompassing about 30% of the nation’s public school population—have adopted the NGSS. Other states and districts continue to consider adoption. Additionally, a growing number of districts in non-adopting states are embracing the NGSS as the best way to move scientific literacy forward. Many of these are large districts that see the need to significantly change how they approach science education regardless of the state-level politics. As a result, the NGSS are significantly influencing science education throughout the country. The excitement around the NGSS I saw at the NSTA national conference in Chicago this year was palpable. Yes, the conference was in an adopting state, but many teachers attending from non-adopting states were also excited and eager to learn more about the standards.

From the beginning, adoption needed to proceed at a pace befitting each state, occurring when, and if, it made sense. Each adopting state, even those who were not lead states due to their undertaking long reviews and public comment periods, can lay claim to owning the NGSS. As such, they can and should choose their own timing. A host of issues face states beyond adopting and implementing new science standards. These issues include developing timelines for adopting instructional materials, revising science standards statutes, and building the will within a state’s education community to make the changes called for in A Framework for K–12 Science Education (NRC 2012) and the NGSS.
Any teacher will tell you that adopting and implementing the NGSS cannot be done without a way to assess. Given the political climate around assessments, the conversation can be harrowing. As a key first step, the NGSS adopter states are committed to building classroom capacity. The focus has been, and must be, on classrooms first rather than building a test. The more we focus on educators and how to make the NGSS real in classrooms before developing an assessment, the better. Assessments that support classroom practice will come as we learn more from classroom experience.

The way the NGSS outlines how students show proficiency makes sense, so teachers are embracing it. That doesn’t mean everyone is an expert. (Research from various places, including The Cambridge Handbook of Expertise and Expert Performance [Ericsson et al. 2006], show that it takes many hours of practice before expert thinking is acquired.) But it does mean that change is in the air, and we must learn more to do better for our students.

It’s time to move from valuing what we measure to measuring what we value. In Kentucky, for instance, the state department of education has hired a “thought partner” before awarding assessment contracts to ensure that any new assessment fully assesses the NGSS. California is using a similar structure with two different groups as they consider new science assessments. So, I am encouraged with the direction and pace of implementation. A thoughtful and deliberate approach has always made the most sense. It is tough to have the courage to be patient, but it is a necessity, not for the adults but for the students.

What have we learned?

My presentation at NSTA’s national conference focused on the top 10 things I learned in 2014 through working with educators and state staff on the various issues we confront. Here are the 10 things, in no particular order:

1. Eliminating the black box is tough.

A black box is created when current science learning is predicated on future science learning. This means that when you say to your students, “You will not understand this until next year,” you create a mystery rather than understanding. The NGSS provides an opportunity to look at science instruction coherently by connecting the different disciplines to better understand a phenomenon, removing the black box. Understanding the role of photosynthesis in the cycling of matter, for example, means you must understand a little about physical sciences in terms of matter and Earth science in terms of distribution of matter.

2. Teaching topics vs. understanding phenomena.

Teaching science is about helping students understand the world around them, both natural and designed. Teaching topics like gas laws, volcanoes, or photosynthesis without connecting them to core ideas that help students explain the world provides no reason for them to learn or retain that information. Gas laws describe part of the structure and properties of matter. The deeper understandings of gas laws are found in the NGSS, but they are couched in explaining the bigger picture of structure of matter. The understandings needed for gas laws are spread throughout the years and across three core ideas in high school physical science. Understanding forces, energy, distribution of energy, and interactions of particles is far more powerful in explaining the world than simply calculating Charles’s law.

3. Simply reading the NGSS does not lead to NGSS expertise.

In our work with the Educators Evaluating the Quality of Instructional Products (EQuIP) rubric, we have seen that professional development that dwells only on the NGSS does not help educators see the innovations required in the NGSS. So, having educators engage in EQuIP, curriculum design, task design, or even an intense discussion of standards that preceded the NGSS stimulates greater understanding. Professional development should also push educators to think outside their grade band and discipline when considering the NGSS (see numbers 9 and 10).

4. If you can eat it, it’s probably not a model.

Understanding the science and engineering practices takes time. There are traditional “models” in classrooms across the country of which I imagine about 80% are edible. Models that students construct and use for the NGSS classroom are quite different. Students need to use models to explain or predict phenomena using evidence. Most “edible” models do not allow for that experience. Scientific and engineering practices are what students do, not teaching strategies. Students should be
able, for example, to identify the components of a model, articulate the relationship of those components, and explain or predict future phenomena based on the model. For more information, see the Appendix of the Evidence Statement (www.nextgenscience.org/ngss-high-school-evidence-statements).

5. Crosscutting concepts are still the third dimension.

The NGSS have three dimensions: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. Crosscutting concepts are still the hardest dimension to implement but also incredibly powerful. This dimension helps students connect what they learn to the world around them in a meaningful way. It’s hard, but clear instruction about how crosscutting concepts fit with the other dimensions will change science education.

6. Phenomena are underplayed and underappreciated.

The Framework and the NGSS are very focused on phenomena. We need to bring the wonder back to science classrooms, which can be done through studies of phenomena. We have found this is tough to do because of our conditioning, but it is essential to making science real to students.

7. Bundling is not easy.

Bundling performance expectations in the study of phenomena is critical to painting a coherent science picture for students. There is no single correct way to bundle, rather it must make sense to the teacher. So, pick a phenomenon and look at all the standards to find a way to better explain the world. Discuss it with colleagues. Bundling will only get easier with discussion and practice.

8. Communicate, communicate, communicate and then communicate some more.

The NGSS represent a lot of what we want science classrooms to be, but they also depart from how most of our parents were taught. We must make every attempt to be clear about purposes, development processes, and how the NGSS will better prepare our students for the world.

9. Leadership makes the difference.

Teachers make the difference in classrooms. It is time we realize that our profession also makes a difference in society. Teachers are leading the way to our future. What we see in states and districts that are effectively implementing the NGSS is that teachers and administrators are assuming greater leadership roles. Yes, there is more to learn and, yes, it is not easy, but the early implementers have shown us that quality leaders make the difference.

10. 3-D Learning is hard. We do not help teachers or students by pretending it’s not.

If anyone claims to know everything about the three-dimensional learning embodied in the NGSS, be skeptical. This is hard. But, like other professions that deal with hard changes, we will surmount these challenges, too. Learning how to create a 3-D culture in our classrooms takes time and effort.

As was mentioned earlier, achieving expertise (thinking like an expert) takes many hours. We teachers should, as engineers do, give ourselves time to learn and room to grow. We will not get it right the first time, and that is okay. We will get better at NGSS instruction, but we must first acknowledge that it will take time and we will have varying degrees of initial success. The NGSS represent a great opportunity for students and science education. To me, they also represent a great opportunity for teachers to teach science the way we know we should and to be real leaders as we prepare our students for the future.

References


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Some Tropical Plants Pick the Best Hummingbirds to Pollinate Flowers

Rather than just waiting patiently for any pollinator that comes their way to start the next generation of seeds, some plants appear to recognize the best suitors and “turn on” to increase the chance of success, according to a recent study.

Being picky may increase access to genetic diversity and thus give the plants a competitive advantage over their neighbors, but there is a risk, the researchers say. If the preferred pollinators decline for any reason, the plants may not reproduce as easily and could decline as well.

These findings stem from the discovery that the showy red and yellow blooms of Heliconia tortuosa, an exotic tropical plant, recognize certain hummingbirds by the way the birds sip the flowers’ nectar. The plants respond by allowing pollen to germinate, ultimately increasing the chances for successful seed formation.

“To our knowledge, these findings provide the first evidence of pollinator recognition in plants,” the authors wrote.

In experiments at the Las Cruces Biological Station in Costa Rica, lead author Matt Betts and coauthor Adam S. Hadley exposed Heliconia to six species of hummingbirds and a butterfly. The team discovered that two types of hummers—violet sabrewings and green hermits—achieved more than 80% success in fertilizing the plants.

“The ones that turned it on tended to have long, curved bills that could reach the nectar,” says Betts. “The ones that couldn’t turn it on had shorter bills and couldn’t get as much nectar.”

The two most effective hummingbird species also shared another characteristic: Compared to five other species, they tended to travel more widely across the landscape. The researchers hypothesized that since far-ranging species tend to collect pollen from more distant plants, the pollen would exhibit more genetic diversity and enhance the plant’s competitive fitness. Pollen from nearby plants could come from close relatives and thus have reduced genetic diversity, the authors wrote.

“The mechanism may have evolved to enable the plant to sort out pollinators that are likely to be carrying high-quality pollen from those carrying poor-quality pollen,” adds Betts. “It’s a big energy savings. If you bother to make a seed and fruit every time you get pollen, that’s a lot of energy expenditure; you could be making a seed from your siblings’ genes. If you make a seed or fruit only from distant high-quality pollen, it could be an adaptive advantage.”

It’s possible, Betts says, that other examples of pollinator recognition could occur in tropical forests.

—Oregon State University (www.eurekalert.org/pub_releases/2015-03/osu-stp030215.php)

Study Shows Cats Prefer Their Own Beat

As more animal shelters, primate centers, and zoos start to play music for their charges, it’s still not clear whether and how human music affects animals.

Now, a recent study shows that while cats ignore our music, they are highly responsive to “music” written especially for them.
“We are not actually replicating cat sounds,” says lead author Charles Snowdon. “We are trying to create music with a pitch and tempo that appeals to cats.”

The first step in making cat music is “to evaluate music in the context of the animal’s sensory system,” he says. Cats, for example, vocalize one octave higher than people, “So it’s vital to get the pitch right. Then we tried to create music that would have a tempo that was appealing to cats.” One sample was based on the tempo of purring, the other on the sucking sound made during nursing.

In the tests, Snowdon and co-author Megan Savage brought a laptop and two speakers to the homes of 47 cats and played four sound samples: two from classical music and two “cat songs” created by composer David Teie.

The music began after a period of silence, and the cat’s behavior was noted. Purring, walking toward the speaker, and rubbing against it were adjudged positive response, while hissing, arching the back, and raising the fur were negative.

The cats were significantly more positive toward cat music than classical music. They began the positive response after an average of 110 s, compared to 171 s for the human music. The slow responses reflected the situation, Snowdon says, “Some of them needed to wake up and pay attention to what was going on, and some were out of the room when we set up.”

The study follows a 2009 report by Snowdon and Teie, which showed that a monkey called the cotton-top tamarin responded emotionally to music composed specifically for them. That work led Snowdon and Teie to believe that “the same features that are effective in inducing and communicating emotional states in human music might also apply to other species.” These features include pitch, tempo, and timbre.

With more people trying to “enrich” the lives of animals by playing music to them, Snowdon hopes the approach he and his colleagues take will help put some facts on the table.

You can listen to the researchers’ “cat music” online at www.eurekalert.org/multimedia/pub/88063.php.

—University of Wisconsin–Madison (www.eurekalert.org/pub_releases/2015-03/uow-mom031015.php)

Robot Model Shows Body Posture May Affect Infant Memory and Learning

In a recent study, researchers have found that posture is critical in the early stages of acquiring new knowledge. The findings offer a new approach to studying the way “objects of cognition,” such as words or memories of physical objects, are tied to the position of the body.

“This study shows that the body plays a role in early object name learning and how toddlers use the body’s position in space to connect ideas,” says lead author Linda Smith. “The creation of a robot model for infant learning has far-reaching implications for how the brains of young people work.”

Using both robots and infants, researchers examined the role bodily position played in the brain’s ability to “map” names to objects. They found that consistency of the body’s posture and spatial relationship to an object as an object’s name was shown and spoken aloud were critical to successfully connecting the name to the object.

The new insights stem from the field of epigenetic robotics, in which researchers are working to create robots that learn and develop like children, through interaction with their environment.

“A number of studies suggest that memory is tightly tied to the location of an object,” Smith says. “None, however, have shown that bodily position plays a role or that, if you shift your body, you could forget.”

To reach these conclusions, the study’s authors conducted a series of experiments, first with robots that were programmed to map the name of an object to the object through shared association with a posture, then with children ages 12 to 18 months.

In one experiment, a robot was first shown an object situated to its left, then a different object to the right; then the process was repeated several times to create an association between the objects and the robot’s two postures. Then with no objects in place, the robot’s view was directed to the location of the object
on the left and given a command that elicited the same posture from the earlier viewing of the object. Then the two objects were presented in the same locations without naming, after which the two objects were presented in different locations as their names were repeated. This caused the robot to turn and reach toward the object now associated with the name.

The robot consistently indicated a connection between the object and its name during 20 repeats of the experiment. But in subsequent tests where the target and another object were placed in both locations—so as to not be associated with a specific posture—the robot failed to recognize the target object. When replicated with infants, there were only slight differences in the results: The infant data, like that of the robot, implicated the role of posture in connecting names to objects.

“These experiments may provide a new way to investigate the way cognition is connected to the body, as well as new evidence that mental entities, such as thoughts, words, and representations of objects, which seem to have no spatial or bodily components, first take shape through spatial relationship of the body within the surrounding world,” Smith says.

—Indiana University (www.eurekalert.org/pub_releases/2015-03/ iu-rmf031815.php)

Shape-Shifting Frog Discovered in Ecuadorian Andes

A frog in Ecuador’s western Andean cloud forest changes skin texture in minutes, appearing to mimic the texture it sits on. The amphibian, called *Pristimantis mutabilis*, or mutable rainfrog, is believed to be the first known to have this shape-shifting capability.

The researchers, Katherine and Tim Krynak, originally spotted the small, spiny frog, nearly the width of a marble, sitting on a moss-covered leaf about a yard off the ground on a misty July night in 2009. The Krynaks had never seen this animal before, though Tim had surveyed animals on annual trips to Las Gralarias since 2001, and Katherine since 2005.

They captured the little frog and tucked it into a cup with a lid before resuming their nightly search for wildlife. They nicknamed it “punk rocker” because of the thorn-like spines covering its body.

The next day, Katherine Krynak pulled the frog from the cup and set it on a smooth white sheet of plastic for Tim to photograph. It wasn’t “punk”—it was smooth-skinned. They assumed that, much to her dismay, she must have picked up the wrong frog.

“I then put the frog back in the cup and added some moss,” she says. “The spines came back ... We simply couldn’t believe our eyes; our frog changed skin texture!

“I put the frog back on the smooth white background. Its skin became smooth.”

“The spines and coloration help them blend into mossy habitats, making it hard for us to see them,” she says.

During the next three years, a team of fellow biologists studied the frogs. They found the animals shift skin texture in a little more than three minutes.

Coauthors Juan M. Guayasamin and Carl R. Hutter also discovered that *Pristimantis sobetes*, a relative with similar markings but about twice the size of *P. mutabilis*, has the same shape-shifting trait. *P. sobetes* is the

In Brief:

• Patterns appearing on both the very large and very small scale are extremely rare, but researchers have found a similar pattern in two apparently unrelated systems—skin cells and fairy circles in the Namibian desert. Desert fairy circles are considered one of nature’s greatest mysteries because no one knows how they form. These fairy circles are large barren patches of earth ringed by short grass dotting the desert like craters on the moon or big freckles. The distribution of fairy circles throughout the desert may look random, but turns out to have a pattern that very closely matches the distribution pattern of skin cells. A pattern spanning such drastically different size scales—microscopic skin cells and the desert landscape—is almost unheard of in nature. The researchers suspect the patterns might be similar because both skin cells and fairy circles are fighting for space. If true, scientists might one day be able to glean information about systems just by analyzing patterns. For example, they could search for signs of life on other planets or moons, where images are usually the only data initially available. Okinawa Institute of Science and Technology Graduate University (www.eurekalert.org/pub_releases/2015-04/oios-mdf040615.php)
only relative that has been tested so far.

The researchers hope to discern whether more relatives have the ability to shift skin texture and if that trait comes from a common ancestor. If *P. mutabilis* and *P. sobetes* are the only species within this branch of Pristimantis frogs to have this capability, they hope to learn whether they retained it from an ancestor while relatives did not, or whether the trait evolved independently in each species.

—Case Western Reserve University (www.eurekalert.org/pub_releases/2015-03/cwru-sfd032315.php)

This image shows skin texture variation in one individual frog (*Pristimantis mutabilis*) from Reserva Las Gralarias.
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All the Water in the World

By Emily Morgan and Karen Ansberry

When you look at a globe, water on Earth seems abundant. More than two-thirds of the surface of our planet is covered in water, but a closer look reveals that only a small fraction of that water is freshwater, most of which is located underground or frozen in glaciers and polar ice caps. In fact, only about 1% of all the water on Earth is accessible freshwater. This issue’s column explores the locations and forms of water, how it is distributed in various reservoirs, and why we need to protect and conserve “all the water in the world.”

This Issue’s Trade Books

*All the Water in the World*
By George Ella Lyon
Illustrated by Katherine Tillotson
Atheneum Books for Young Readers. 2011.
ISBN: 978-1-4169-7130-6
Grades K–2

Synopsis
Rhythmic language and vibrant artwork describe why “all the water in the world is all the water in the world” that just keeps cycling through various forms and places.

*One Well: The Story of Water on Earth*
By Rochelle Strauss
Illustrated by Rosemary Woods
Holiday House. 2010.
ISBN: 978-1-55337-954-6
Grades 3–5

Synopsis
Beautiful paintings and informative text describe all the water on our planet as a single well that all living things share. Tables and graphs are used to inform the reader of the distribution of water on Earth and the need to conserve it.

Curricular Connections

One of the goals of the *Next Generation Science Standards* is to increase coherence in K–12 science education (NGSS Lead States 2013). The NGSS were written using the learning progressions set forth by *A Framework for K–12 Science Education* (NRC 2012). Appendix E of the NGSS contains a comprehensive table that outlines the progression of disciplinary core ideas throughout the K–12 years by using grade band endpoints. This issue’s column demonstrates the learning progressions for topic ESS2.C: The roles of water in Earth’s surface processes. In grades K–2, the grade band endpoint states that by the end of grade 2, students should understand that, “water is found in many types of places and in different forms on Earth.” This basic concept is built upon in grades 3–5, when students learn that “Most of Earth’s water is in the ocean and much of the Earth’s fresh water is in glaciers or underground” (NGSS Lead States 2013, Appendix E, p. 3). These foundational concepts build upon one another and set the stage for more sophisticated understandings about Earth’s water that students will explore in middle and high school.

In this issue’s K–2 lesson, students use images of the Earth from space to identify liquid and solid water on Earth and develop a model to show where the water on Earth is located. The lesson for grades 3–5 builds upon the K–2 concepts by exploring the actual percentages of salt water and freshwater on Earth and the distribution of water in various reservoirs. The two lessons are on the same topic but advance in level of sophistication.

Emily Morgan (emily@pictureperfectscience.com) and Karen Ansberry (karen@pictureperfectscience.com) are authors of the Picture-Perfect Science series from NSTA Press.
Grades K–2: All the Water in the World

Purpose
By observing actual images of Earth and reading a book about Earth’s water, students will identify where both liquid and solid water (ice) are found on Earth.

Engage
Show students the famous NASA photograph titled, “The Blue Marble” (see Internet Resources). Explain that this photograph of Earth was taken in 1972 by the Apollo 17 astronauts as they were traveling to the Moon. Ask students why they think the photograph was titled, “The Blue Marble.” (Earth is the same shape as a marble, it is mostly blue, and the swirls of clouds look like the swirls on some marbles.) Ask students what makes the blue color on Earth (water/oceans). Then ask if they think there is more land or water on Earth. In order to answer this question, they will need to see the whole Earth, not just one side. Show students images from the more recent NASA photo gallery “The Blue Marble,” which includes animations of Earth’s rotation (see Internet Resources). Tell students that these newer pictures were taken by satellites orbiting Earth and because of improved technologies are much clearer than the original “Blue Marble” photograph from 1972. Students will realize from these photos that the amount of water on Earth greatly exceeds the amount of land.

Explore
Ask students where else water can be found on Earth besides the oceans (lakes, rivers, streams, ponds, puddles, and so on). Then ask, “Where is the closest water source to our school? How can we find out?” Students might suggest looking at a map. Project the Google Maps app and enter your school address. Tell students that this is a map of the area around the school and that on this map, water appears as the color blue. Slowly zoom out and stop when you see a body of water. Determine if it is a pond, stream, lake, or river. Keep zooming out, pausing to take note of the bodies of water on the map, until you can’t zoom out any farther. Ask students what the green colors on this map represent (land); what the white areas represent (ice); and if ice is water (yes). Show students the areas at the north and south poles that are covered with ice, which is water in a solid form.

Explain
Show students the cover of All the Water in the World and tell them that this book is about Earth’s water—where it can be found and what forms it can take. Read the book aloud and stop after reading page 11, which says, “Water doesn’t come. It goes. Around.” Ask students what they think the author means by those lines. Have them listen for the answer on the following pages (CC ELA Connection: Reading: Informational Text – Integration of Knowledge and Ideas). From the reading, they should recognize that all the water in the world has been here before in different places and different forms. Make a list together of the different bodies of water they can think of that are found on Earth, including oceans, rivers, lakes, ponds, streams, glaciers, and ice caps. Reread the last five pages of the book, in which the author asks the reader not to waste water. Ask students why anyone would need to worry about wasting water if most of the planet is covered with water. Refer back to the “Blue Marble” pictures in the engage phase. Remind students that most of the Earth’s water is in the oceans. Explain that ocean water is salt water and that we cannot drink salt water. It would make us very sick. Our crops cannot be watered with salt water because the plants would die. Most land animals cannot survive by drinking salt water either. So, most of the water on Earth is not us-

Materials
- Computers or tablet devices
- Google Maps and internet connection
- Projector or interactive whiteboard
- Paper plates (1 per student)
- Art supplies, such as clay, paint, and markers

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able water. Next, point out the ice caps on the North and South poles. Explain that this water is not usable either because it is frozen. Explain to students that a very small fraction, only about 1%, of the water on our entire planet, can be used by us. So, it is extremely important to conserve that water to keep us and all the living things on our planet healthy.

Elaborate

Reread pages 18–22 of All the Water in the World, which describes how some places on Earth have a “wealth of water” and others are desperately waiting for rain. Have students guess where the wettest places on Earth might be (the places with the most rainfall per year). Then model how to find your answer using an internet search. (If you have devices for each student or pair of students, have them locate these places on the map, taking note of the surrounding bodies of water and zooming out to see where they are located on Earth). For example, according to the Guinness Book of World Records, the wettest place on Earth is Mawsynram, India, at 467 inches of rain per year. Have students enter the name of the city and country in the search box of Google maps. Then, have them make observations of the surrounding bodies of water. Next, research the driest places on Earth and have students find them using Google maps, noting the closest bodies of water and their locations on Earth.

Evaluate

Challenge students to develop a model to represent the land and water visible on one of the images from the 2002 NASA Blue Marble gallery. They can create their model on a sturdy paper plate using art supplies such as clay, markers, and/or paint. They must also create a key that identifies land, liquid water (oceans, lakes, rivers), and frozen water (ice caps and glaciers). Students can display their models in the classroom.

Connecting to the Next Generation Science Standards (NGSS Lead States 2013)

Grades K–2
2-ESS2 Earth’s Systems
www.nextgenscience.org/2ess2-earth-systems

<table>
<thead>
<tr>
<th>Performance Expectations</th>
<th>Connections to Classroom Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectations listed below. Additional supporting materials/lessons/activities will be required.</td>
<td>Students use Google maps to locate liquid and solid water on Earth.</td>
</tr>
<tr>
<td>2-ESS2-3 Obtain information to identify where water is found on Earth and that it can be solid or liquid.</td>
<td>Students create a model based on one of the “Blue Marble” images of Earth and develop a key to show liquid water, solid water, and land.</td>
</tr>
<tr>
<td>K-2-ESS2-2 Develop a model to represent the shapes and kinds of land and bodies of water in an area.</td>
<td>Students obtain information from a read aloud and Google maps to determine where water is located on Earth.</td>
</tr>
</tbody>
</table>

Science and Engineering Practice

Obtaining, Evaluating, and Communicating Information

Students obtain information from a read aloud and Google maps to determine where water is located on Earth.

Disciplinary Core Idea

ESS2.C The Roles of Water in Earth’s Surface Processes

- Water is found in the oceans, rivers, lakes, and ponds. Water exists as solid ice and in liquid form.

Using the features of Google maps, students locate sources of solid and liquid water on Earth.

Crosscutting Concept

Stability and Change

Students will explain that some events take a long time to happen whereas other events happen rapidly.
Grades 3–5: One Well

Purpose
By describing and graphing the percentages of water from various reservoirs on Earth, students will learn that nearly all the water on Earth is in the ocean and that only a tiny fraction of Earth’s water is fresh and accessible.

Engage
Show students the cover of the book, One Well: The Story of Water on Earth, and ask them what they think the title, “One Well” means. Next, give each student a small cup of water to drink. As they drink their water, read the first paragraph on page 8 titled, “Recycling the Water in the Well,” which explains that the water they are drinking today may have “rained down on the Amazon rain forest five years ago,” “been steam escaping a teapot a hundred years ago,” or “quenched the thirst of a dinosaur a hundred million years ago.” Ask students how it could be possible that the water they just drank could have also existed so long ago in so many different places. Students will likely bring up the water cycle they learned about in the early elementary grades. Read the rest of pages 8 and 9 about how water recycles on Earth. Now, ask students again about the title of the book One Well. They should realize that the author is referring to all of the water on our planet being like one enormous well, because there is a finite amount of water on Earth (Reading: Informational Text – Integration of Knowledge and Ideas).

Explore
Give each group of four students a globe and ask them where the water in our “one well” can be found. Ask students what color on the globe represents water (blue); what color(s) represents land (answers will vary depending on the globe); what color represents ice or snow (white); and if ice is part of “the well” (yes). Using the globe, have groups make a list of the bodies of water on Earth in which water is found. They will likely list oceans, rivers, lakes, streams, ice caps, and so on. Next, ask them to estimate which water sources contain the most water on Earth, then rank their list in order from the largest percentage of the “well” to the smallest percentage.

Explain
Read pages 4–10 of One Well aloud and have students listen for the actual distribution of water on Earth. They will learn from the reading that there are some sources of water they cannot see on a map, such as groundwater, moisture in the soil, and water in the atmosphere. After reading, turn back to page 7, which lists the percentage of water in the oceans, ice caps and glaciers, groundwater, freshwater lakes, inland saltwater seas, moisture in the soil, water in the atmosphere, and rivers. Tell students that a graph might help them get a better idea of these percentages. Logon to the Create a Graph website (see Internet Resources) and show students how to make a graph using the data listed in the book. The first step is to choose the type of graph you would like to make—bar graph, line graph, circle graph (pie graph), or XY. Ask students what type of graph they think would be best for comparing the parts of the “One Well.” They should realize that a circle graph would be best for comparing the parts of a whole. Have students enter their data and print their circle graphs representing the distribution of water on Earth.
Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

**Grades 3–5**

2-ESS1 Earth’s Systems: Processes That Shape the Earth

[www.nextgenscience.org/2es-earths-systems-processes-shape-earth](http://www.nextgenscience.org/2es-earths-systems-processes-shape-earth)

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<td></td>
</tr>
<tr>
<td>5-ESS2-2 Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.</td>
<td>Using an online graphing program, students graph the percentages of water on Earth from various reservoirs.</td>
</tr>
</tbody>
</table>

**Science and Engineering Practice**

| Developing and Using Models | Students develop a model to share distribution of salt water, fresh water, and usable water on Earth to share with younger students. |

**Disciplinary Core Idea**

<table>
<thead>
<tr>
<th>ESS2.C The Roles of Earth’s Water in Earth’s Surface Processes</th>
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</thead>
<tbody>
<tr>
<td>- Nearly all of Earth’s available water is in the ocean. Most fresh water is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere.</td>
</tr>
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<table>
<thead>
<tr>
<th>Crosscutting Concept</th>
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<tbody>
<tr>
<td>Scale, Proportion, and Quantity</td>
</tr>
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</table>

**Elaborate**

Show students the NASA video *Show Me the Water* and have them listen for the percentages of salt water, fresh water, and usable freshwater on Earth. They will learn that about 97% is in the oceans (salt water) and about 3% is fresh water. Of the 3% of fresh water, only about 1% is accessible freshwater—about 2% is frozen in the icecaps and glaciers. Challenge students to create a simple model that might help them teach younger students how much water on Earth is salt water, how much is fresh water, and how much is accessible fresh water (CC Connection: Mathematical Practices). For example, students could use a clear container or baggie of 100 goldfish crackers to represent all of the water in the “well,” pull out 3 of the 100 to represent the approximately 3% of freshwater, then pull out one of them to represent the approximately 1% of freshwater. They...
Connecting to the *Common Core State Standards* (NGAC and CCSSO 2010)

This section provides the *Common Core for English Language Arts and/or Mathematics* standards addressed in this column to allow for cross-curricular planning and integration. The Standards state that students should be able to do the following at each grade level.

**English/Language Arts**

Reading Standards for Informational Text K–2 and 3–5: Integration of Knowledge and Ideas

- Grade 2: Describe how reasons support specific points the author makes in a text.
- Grade 5: Explain how the author uses reason and evidence to support particular points in a text, identifying which reasons and evidence support which points

Speaking and Listening Standards 3–5: Comprehension and Collaboration

- Grade 5: Report on a topic or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.
- Grade 5: Include multimedia components and visual displays in presentations when appropriate to enhance the development of main ideas or themes.

Furthermore the Common Core for ELA provide a standard related to the Range of Text Types for K–5 where it indicates that students in K–5 should apply the Reading standards to a wide range of texts to include informational science books.

**Mathematics**

Mathematical Practices Standards

MP.4 Model with mathematics

could do something similar with 100 ml of water, 100 stickers, 100 mini marshmallows, and so on.

**Evaluate**

Have students create a presentation to share with younger students about Earth’s water. The three main points they should incorporate are:

1. Where water is found on Earth;
2. How much of the water on Earth is salt water, freshwater, and usable freshwater (using their model); and
3. Why we can think of all the water on Earth as “One Well” (how the water on Earth remains constant and is continually recycled) (CC ELA Connection: Speaking and Listening – Presentation of Knowledge and Ideas).

**References**

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO).


**Internet Resources**

Create a Graph
http://nces.ed.gov/nceskids/createagraph/

Google Maps
www.google.com/maps

NASA Show Me The Water Video
www.youtube.com/watch?v=4HSFKwho7MQ

The Blue Marble Photograph from Apollo 17 (1972)
http://earthobservatory.nasa.gov/IOTD/view.php?id=1133

The NASA Blue Marble Gallery (2002) Includes several views and animations
http://earthobservatory.nasa.gov/Features/BlueMarble/BlueMarble_2002.php
Write for Science and Children!

Your 2000-word manuscript should describe a set of connected lessons or investigations that build an idea or content area. They should include assessments (pre-, post- and formative) as well as enough detail that another teacher could replicate the lessons in the classroom. Examples of student work are encouraged. Don’t forget to take photographs of students safely participating in the activities, and secure parent permissions for their publication. Handy with technology? Create videos, too!

Don’t see a theme that fits your idea? Don’t let that stop you from writing! We always make room for good manuscripts on any elementary science topic.

February 2016: STEAM: Science, Technology, Engineering, Art, Math
Deadline August 1, 2015

Art brings in the qualities of creativity and innovation. These two elements are major factors in a country’s prosperity and serve as a hook to get children more engaged in science, technology, engineering, and math. What may come to mind initially when considering art is the visual arts—painting, sculpting, and drawing—but movement, music, acting, and other art forms are also important to consider. The difficulty in creating learning opportunities within the STEAM context is assuring the integrity and learning of all components. An art lesson without the STEM or a science lesson without the TEAM is not what STEAM is about. Incorporating greater rigor and abstract thinking can build understanding. Consider the following statements concerning STEAM as you create your manuscript:

• The arts reinforce or strengthen learning in the STEM field, and STEM strengthens the arts.
• Connecting the arts to STEM can bring clearer meaning to abstract ideas.
• The entire teaching team may become involved in creating STEAM opportunities, with important contributions by the art, music, PE, and classroom teachers, but teachers must learn all of the components of the STEAM curriculum components to support one another.
• STEAM can build stronger and more cooperative student teams, with each student contributing through their strengths and building on the success of the group.
• STEAM involves using the whole brain. The whole brain is needed to foster and strengthen creativity and innovation. The “left” side of our brain is the logical side, and supports creative and instinctive thinking.

March 2016: Earth and Human Activity
Deadline September 1, 2015

Understanding the impact of human activity on an environment begins with understanding the needs of animals and other living things, including humans, that survive in that environment. The impact of humans on the land, water, air, and living things can then be determined and solutions derived. Humans are able to find solutions to natural hazards and respond to these through implementing strategies through physical actions and structures. Some of the concepts developed in Earth and Human Activity include:

• Living things all need natural resources. The resources may vary from any given living thing to another and from one location to another.
• Although natural hazards impact living things, human are sometimes able to provide protection through predicting causes and effects. They can then take steps to reduce the impact.
• Some natural resources are renewable, others are not. The use of these resources affects the environment in multiple ways.
• Humans can make decisions and develop solutions that can reduce their impacts on land, water, and air. (NGSS: ESS3)

Find the complete Call for Papers at www.nsta.org/sandccall.

See the author guidelines at www.nsta.org/elementaryschool/msguidelines-sc.aspx
April/May 2016: Methods and Strategies  
Deadline October 1, 2015

The Methods and Strategies column has served as an important element in providing current educational research to the readers of Science and Children. Manuscripts submitted to meet this theme should directly connect science teaching with research on teaching and learning. This is to be done by sharing an account of a method or strategy used in the classroom and explaining how its use is supported by research. Emphasis should be on this support of student learning. While the presentation of the method or strategy is often content-based, the method or strategy should be applicable to other settings and other core ideas.

Summer 2016: From Molecules to Organisms  
Deadline November 1, 2015

Understanding structure and function of life forms helps students understand how living things survive and grow. One of the typical places to start is with plants since students are able to gather first-hand evidence and build knowledge about structures and growth. Connecting to their own experiences, children are able to relate to patterns of behavior of parents and offspring but can also relate to behaviors in other animals. Learning about common elements of the life cycles of living things helps in the development of understanding the patterns of life and supports making predictions. This continuum of learning might include:

- Different animals have different body parts and use them in different ways. The manner in which these parts are used support the animal’s ability to grow, reproduce, and survive.
- Animals have offspring and may behave in ways that support the survival of their offspring.
- Animals capture and convey external stimuli, and they respond to gathered information in ways that help guide their actions. Some plants also respond to external stimuli.
- Plants and animals have diverse life cycles.
- Plants require material for growth, mainly from air and water.  
  (NGSS: LS1)

Not ready to pen a feature article?  
Consider writing a column. These shorter, focused pieces are the perfect way to share your experiences with the wider elementary science community.

Early Childhood Resources Review

Science & Children has launched this column that provides reviews of some of the best resources designed specifically for teaching science to young children. Reviewers select resources that present relevant and appropriate science content and describe inquiry-based approaches to engaging young children in the practices of science and engineering, as described in the Next Generation Science Standards. For specific resource review criteria, more information concerning providing a review for publication consideration, or to suggest a review be provided for a specific resource, contact column editor Ingrid Chalufour at ingridchalufour@gmail.com.

Methods and Strategies

We are considering this manuscript for the Methods and Strategies column. This column provides ideas and techniques to enhance science teaching. This is S&C’s “think piece” and connects science teaching with research on teaching and learning. This is done by sharing an account of a method or strategy used in the classroom and explaining how its use is supported by research. While the presentation of the method or strategy is often content-based, the method or strategy should be applicable to other settings and other content. Length 2000 words

Engineering Encounters

We are seeking column submissions that present classroom-tested, novel, and engaging lessons for preK–5 students. They should include all of the components necessary for an engineering investigation to be completed and assessed, from design to implementation. Be sure to bring the voices of students and the teacher to the manuscript. In other words, focus on application of instruction that provides a peek into the classroom. We are also interested in submissions that provide background information for the teacher that will support the teacher’s ability to construct his or her own engineering lessons. This might include suggestions as to where more information can be found concerning high-quality lessons, strategies for structuring lessons, resources that support teaching and learning, and strategies for use in evaluating lessons and materials. Length: 2000 words.
As teachers in childcare programs prepare to say goodbye to the children starting kindergarten in September, we reflect on their growth of understanding. We will be resetting our developmental expectations for the next class of children, who may be a whole calendar year younger than our last group, and reevaluating what activities and materials are appropriate for them.

One of the principles of A Framework for K–12 Science Education is that “understanding develops over time” (NRC 2012, p. 26). This is also one of the principles of the NSTA Early Childhood Science position statement. The National Association for the Education of Young Children (NAEYC) recognizes the importance of allowing children to spend sustained time with experiences (see Internet Resources). All three documents identify the concept of progressions of learning, “building progressively more sophisticated explanations of natural phenomena” (NRC 2012, p. 25).

While the three preschool classes I teach (children ages 2 through 5) take place in the same room, I change the materials based on the developmental readiness of the children. For example, to help children begin building toward a grade 2 understanding of the NGSS performance expectation 2-PS1 Matter and Its Interactions (see Internet Resources), we work with materials with varied properties (e.g., various recipes of play dough, ceramic clay, and garden soil). Through discussions of “wet” and “dry” while making play dough, two-year-olds learn vocabulary and describe one property of matter (Ashbrook 2011). As they mix, children may also notice small grains making up a cupful of salt and the slippery feeling of oil compared to the wet feeling of water. Four-year-olds who have had these experiences may ask questions about the changes in properties through heating. This can be further explored by firing the ceramic clay.

Introducing a natural, water-based ceramic clay formulated for safe use by children expands children’s experiences with materials. The children may use tools such as craft sticks to manipulate the clay. As children progress from making balls to making more complex models, they are ready to learn techniques such as how to adhere pieces of clay so they will stay together when dry.

Peggy Ashbrook (scienceissimple@yahoo.com) is the author of Science Is Simple: Over 250 Activities for Preschoolers and teaches preschool science in Alexandria, Virginia.

References

Internet Resources
NSTA Early Childhood Science Education position statement www.nsta.org/about/positions/earlychildhood.aspx
NGSS Table: 2-PS1 Matter and Its Interactions www.nextgenscience.org/2ps1-matter-interactions
Forming Knowledge of Clay Properties

Objectives

Children will explore the properties of ceramic clay formulated for children’s use, learn related vocabulary, and describe the changes in property when water is added.

1. Read the safety tips about art materials (see Internet Resource) and use the searchable certified products list to purchase ceramic clay with an AP seal. Gray or white clay is preferable because red clay can stain clothing.

2. Begin with play dough if students have never used it before introducing the clay. This will allow them to become familiar with manipulating a three-dimensional material—and for you to assess if children are able to resist putting dough or clay into their mouths.

3. Keep supplies—clay tools and wet paper towels—nearby. Craft sticks are a good tool for inexperienced children. With practice and development, children can use rolling pins, butter knives, and other tools. Use wet paper towels to clean dry clay dust to avoid airborne dust (see Roy 2014).

4. Dampen the clay in advance. Then, model how to make finger impressions in the clay or roll a ball to help put hesitant children at ease. Questions such as, “What can we do with this clay?” and “How did you do that?” focus children’s thinking on the properties of clay. Provide a tub of water for initial hand-rinsing to keep most clay from going into the sink drain.

5. Put aside some worked pieces of clay so children can notice clay drying out and becoming harder.

6. If the stock of clay dries out, ask, “Was it too dry yesterday?” and “What can we do to make it soft again?” Allow children to add water, beginning with a mister or shallow dish to dip fingers into for the two-year-old children. Older children may be able to add water sparingly using a small pitcher.

7. Have the clay available for 30–45 minutes several times a week over many weeks. This will support a progression of understanding of the properties of clay as children experience the clay becoming drier each time. Try storing the clay in a plastic tablecloth tied up with a rope (Rogers and Steffan 2009), which can simply be unfolded on a table to open a clay center.

Through experience with ceramic clay, sand, and the local soil, children will feel the differences in their textures, a beginning understanding of soil science. If your locality has a clay soil, digging in soil and comparing local clay with prepared ceramic clay can help children make the connection that clay is a resource from the Earth.

Internet Resource


References


NSTA Connection

Download a list of additional books and resources at www.nsta.org/sc1507.

Materials

• Play dough (homemade or store-bought)
• Ceramic clay formulated for safe use by children (see Internet Resource)
• Plastic tablecloth and string
• Water to keep clay damp
• Wet paper towels
• Tools such as craft sticks, plastic knives, scrapers, rolling pins, sea shells, acorns, and small water containers
• Tub or bucket large enough for hand rinsing
• Trays to hold drying clay pieces

Manipulating clay teaches children about properties.
Learning progressions are research-based, descriptive continuums of how students develop and demonstrate increasingly more sophisticated and mature understandings over time. For formative assessment purposes, they offer guidance about how learning will generally develop and where students are at any point in time along a learning continuum (Hess 2010). When teachers understand what a pathway for learning looks like related to a core disciplinary idea, and can gather evidence of where students are at points along a continuum, they are better able to design instructional experiences that will move students along that pathway. Formative assessment probes are significant tools for assessing where students are along that continuum.

Empirically tested learning progressions take significant time to develop and publish. Most disciplinary core ideas in science do not yet have a research-validated learning progression; however, significant thought was given to the progression of learning goals articulated in the Framework for Science Education (NRC 2012), the Next Generation Science Standards (NGSS Lead States 2013), and the Benchmarks for Literacy (AAAS 2009). Development of the formative assessment probes in the Uncovering Student Ideas in Science series draws upon these documents to develop probing questions that reveal how students think about core disciplinary ideas in science at different levels of sophistication. This information is used to determine the kinds of instructional experiences children need to achieve understanding. Furthermore, the teacher notes for each of the probes provide valuable guidance on how the probe fits into a progression of learning so that it can be used effectively.

Let’s explore what a K–2 learning progression approach looks like when formatively assessing the core concept of conservation of matter using the formative assessment probe “Snap Blocks” (Keeley 2013; Figure 1).

In developing the K–2 probe for this concept, I examined the K–2 core disciplinary idea in the Framework, PS1.A: A great variety of objects can be built up from a small set of pieces. Objects or samples of a subject can be weighed and their size can be described and measured (NRC 2012). Before understanding that the sum of the parts weigh the same as the whole, students need opportunities to build things from a small set of parts and take them apart. They learn that a whole object is a collection of parts. They practice weighing whole objects, each of the parts, and a collection of the parts. The familiar mathematics manipulative, snap blocks, was selected to provide these experiences and serve as a familiar context for the probe. Once students have had these instructional experiences, the teacher can assess whether they think all the individual parts together weigh the same as when they are put together, or do they think the weight will be different?

The learning path for this probe starts with seeing that things are made of parts, progresses to understanding that parts of an object can be taken apart and put back together, followed by experiencing how a whole object and its parts can be weighed, to finally learning that the sum of all the parts of an object weigh the same as the whole object. Some students may be ready for this conservation of matter idea during the K–2 span, others will grasp it later in grades 3–5. The ideas revealed through the formative assessment probe can be used to determine students’ readiness to use conservation reasoning.

“Snap Blocks” is an example of a basic formative assessment probe used to uncover students’ initial ideas about matter conservation using simple, familiar objects that can be taken apart and put back together. This information is used by the teacher to inform targeted instruction of a learning goal. Once students have met the learning goal, increasingly more sophisticated contexts related to conservation of matter can be introduced and formatively
assessed. In grades 3–5, the Framework builds upon parts and wholes of objects taken apart and put back together to include what happens to objects, materials, or substances in other physical changes, including dissolving, melting, evaporating, and changing size and shape. Notice how students’ are progressing from investigating objects to now investigating conservation of matter using materials, such as clay and wood and simple substances like water, sugar, or salt.

The learning path will continue into middle school when students use the idea of atoms and molecules in explaining conservation of matter. In middle school, students are expected to progress from conserving matter in physical changes to chemical changes, including changes when a gas is involved. The terminology begins to change at this level as the learning progresses from conservation of weight to conservation of mass.

The Uncovering Student Ideas in Science series include several formative assessment probes that can be used to uncover students’ ideas related to conservation of matter. Before you use the probe, examine the curricular and instructional considerations for your grade level in the teacher notes. Also, examine the related ideas from standards that are listed in the teacher notes. This information can help you identify where the probe fits into a progression of learning so that instruction and formative assessment can be matched to an appropriate trajectory of learning.

Page Keeley (pkeeley@mmsa.org) is the author of the Uncovering Student Ideas in Science series (http://uncoveringstudentideas.org) and a former NSTA President.

References
American Association for the Advancement of Science (AAAS). 2009. Benchmarks for science literacy online. www.project2061.org/publications/bsl/online

NSTA Connection
Visit www.nsta.org/sc1507 for the Snap Blocks probe.
NGSS for All Students
Grades K–12

NGSS for All Students shows you how to teach diverse students and connect your lessons to the Next Generation Science Standards (NGSS). The emphasis is on how.

At the core of the book are case studies that vividly illustrate research- and standards-based classroom strategies to engage seven diverse demographic groups. The book also includes additional chapters on how to design a unit with the NGSS and diversity in mind, apply a rubric to examine and improve teaching the NGSS with diverse students, and use the case studies in teacher study groups.

Book: Member Price: $27.96 | Nonmember Price: $34.95
E-book: Member Price: $22.72 | Nonmember Price: $26.21
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Uncovering Student Ideas in Physical Science, Volume 2
39 New Electricity and Magnetism Formative Assessment Probes
Grades K–12

This new volume in the bestselling Uncovering series offers 39 new formative assessment probes focusing on electric charge, electric current, and magnets and electromagnetism. These physical science probes work with everything from demystifying electromagnetic fields to explaining the real reason why balloons stick to the wall after you rub them on your hair. By helping you detect and then address misconceptions with sound science, this new volume has the potential to transform your teaching.

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Guiding Student Investigations
Grades K–6

The authors of The Power of Questioning invite you to nurture the potential for learning that grows out of children’s irrepressible urge to ask questions. The book’s foundation is a three-part instructional model, Powerful Practices, grounded in questioning, investigation, and assessment. To bring the model to life, the authors provide vivid pictures as well as links to special videos and audio recordings. You can actually hear teachers and students engage in questioning and watch two easy-to-adapt examples of the model in action. The book also illustrates how to integrate the Next Generation Science Standards, the Common Core State Standards, and STEM education practices.

Book: Member Price: $14.36 | Nonmember Price: $17.95
E-book: Member Price: $12.02 | Nonmember Price: $13.71

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Grades K–12

This book is a rich source of ideas to make you consider science teaching from a whole new perspective. Teaching for Conceptual Understanding in Science is a collaboration between Richard Konicek-Moran and Page Keeley. The book is a fascinating combination of deep thinking about teaching and learning for understanding; field-tested, classroom-ready strategies that support conceptual understanding in all grades; and personal vignettes with lessons for all educators.

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E-book: Member Price: $22.07 | Nonmember Price: $25.46
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The BSCS 5E Instructional Model
Creating Teachable Moments
Grades K–12

The BSCS 5E Instructional Model can help you deliberately structure and sequence your lessons so you experience more teachable moments in your classroom. Created in the late 1980s by a team led by author Rodger Bybee, the popular BSCS 5E Instructional Model includes five phases: engage, explore, explain, elaborate, and evaluate. The book elaborates on how the model connects to the Next Generation Science Standards (NGSS), STEM education, 21st-century skills, and real classrooms. The BSCS 5E Instructional Model addresses every teacher’s concern: how to become more effective in the classroom—and enjoy more of those teachable moments.

Book: Member Price: $25.56 | Nonmember Price: $31.95
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Book/E-book Set: Member Price: $33.23 | Nonmember Price: $41.54

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E-book: Member Price: $20.77 | Nonmember Price: $23.96
Book/E-book Set: Member Price: $33.23 | Nonmember Price: $41.54

To place an order or download a free chapter, visit www.nsta.org/store
A series of activities helps young students learn about fossils.

By Lisa Borgerding
Fossils are interesting and mysterious to young learners. They are amazed that these things that look like rocks actually used to be alive a long, long time ago! Although fossils fascinate students, there are usually many things they don’t understand about them. When can children begin to make sense of fossils? Fossils are not addressed in the Next Generation Science Standards until the third grade. This NGSS standard focuses on how children can use observations of fossils to make inferences about organisms (structure and function) and their environments (habitats). However, in a learning progression on evolution (Catley, Lehrer, and Reiser 2004) fossils are introduced in the K–2 grade band. These authors suggest that young children can describe fossils; investigate how fossils are made; have tactile experiences with stand-alone fossils and fossils embedded within other rock; represent fossils using drawings, photos, and impressions; and compare fossils to living organisms. Furthermore, research from Taking Science to School (NRC 2007) also indicates that young children are able to comprehend more science than had been previously considered. I had previously successfully used a crinoid fossil activity with a Saturday science class of K–2 students, leading me to believe that young children (K–2) can learn both nature of science and science content from fossils (Akerson and Donnelly 2010). These sources suggest that K–3 children can learn about fossils; what about preschool students?

Preschool- and kindergarten-age children are curious about dinosaurs and paleontology. They frequently engage with relevant children’s programming like Dinosaur Train. In a recent Science and Children article (2014), Peggy Ashbrook says, “beginning efforts in [the tasks of investigating questions, gathering evidence through observations, and holding class discussions to share evidence and ideas] can start in preschool with developmentally appropriate expectations” (p. 24). This lesson provides developmentally appropriate opportunities for preschool and kindergarten children enrolled in a science-focused camp to engage with fossils and the nature of paleontology. As such, Connecting to the Next Generation Science Standards (p. 36) connects the preK activities to the NGSS grade 3 standards, illustrating how young children can begin to meet

FIGURE 1.

Sample claw drawings.
these standards. Based on these standards and literature, I designed lessons to address three big ideas about fossils:

- Fossils are the remains of organisms that used to be alive a long time ago.
- We make inferences about fossil organisms’ form, function, and habitats based on observations.
- Fossils can be similar to organisms alive today.

**Lessons**

**Activity 1: Digging for Whole Fossils**

The introductory lesson began with a 20-minute whole-group discussion about fossils. First, students were given the opportunity to examine some real fossil ammonites. When asked, “What do you think these are?” students replied, “seashell,” “snail,” and “a fossil with a worm in it.” Half of the students indicated when asked that they had heard of fossils and a quarter of the students had heard of paleontologists. Some students explained that paleontologists “dig for bones and fossils” and “bring them back to a lab for them to study.” I added to this, explaining that fossils are the remains of organisms that used to be alive a long time ago and a paleontologist is a special kind of scientist who studies fossils.

Students then explored fossils at greater depth at three different whole-fossil discovery centers. The first center was an outdoor dig where children used small shovels to find baked play dough ammonite and seashell fossils in an outdoor sandbox. The second center was an indoor dig where children used paint brushes to dust sand off of plaster of paris ammonites and shells. The third center contained a bin of real fossil ammonites that children explored using hand magnifiers. Students then rotated freely between the three centers, usually spending 10 to 15 minutes at each center. Each center accommodated about six children at a time, and children could also choose to revisit centers if there was an opening.

At all centers, children were reminded to make careful observations using their vision and touch senses. Also, we reviewed safety rules such as not putting things in their mouth and washing hands after they have completed the activity.

We opened a 15-minute whole-group discussion by reviewing what we dug up. Students eagerly said, “Seashell fossils like the one we were talking about.” We learned that these animals are called ammonites. When asked about their age, students made guesses including 10, 900, and 1600 years old. Students were surprised to learn that these ammonite fossils are animals that lived 200 million years ago. When challenged to imagine where these ammonites once lived, students offered “outside,” “under the ground,” and “at the beach.” We learned that paleontologists used observations of these fossils and what they know about snails and squids living today to infer that ammonites lived in the sea. I explained that paleontologists think ammonites swam to move and most likely ate tiny sea plants and animals.

**Activity 2: Digging for Partial Fossils**

The second lesson required students to make inferences from two partial fossils (dinosaur claw and crinoid) and some whole fossils (ammonite, fish, fern, and trilobite). Students rotated among the three centers that contained new fossils, visiting each center for about 10 minutes (see Fossils on a Budget, p. 35). In the outdoor dig, children used small shovels to unearth baked play dough trilobite, fish, and claw fossils. Children used paint brushes to dust off plaster of paris fish, fern, trilobites, stand-alone (not embedded in rock) crinoids, and crinoids embedded in rocks in the indoor sandbox. Children also used hand magnifiers to explore real trilobites, stand-alone crinoids, and crinoids embedded in rocks at a third center.

As a way to help students make inferences from their partial fossil evidence, children were given a picture of the claw fossil they found earlier. They were asked, “What did this come from? Draw what you think” as teachers circulated and used children’s words to label their images for about 15 minutes. The children most often indicated that the claw fossil was a dinosaur claw or tooth. Other responses included possible organisms such as bats, whales, octopi, and dragons while some responses indicated that students did not understand what fossils were: a train, balloon, and water. We followed up with questions like, “Do you think there were trains and balloons that long ago?” Sample drawings are included in Figure 1, p. 31. Appro
appropriate performance on this claw task was evidenced by students drawing and describing animals which would have a tooth or claw. We had a discussion about whether everybody had “the same idea” for this fossil, and the children agreed that they did not. I explained how paleontologists sometimes have different ideas about fossils, too.

In our next 15-minute whole-group debriefing, students observed a whole-organism trilobite held up at the front of the classroom and were prompted to make guesses about what it was. Unlike the ammonites from the first activity, trilobites do not obviously resemble living things found today. Students indicated that they were unsure of whether these were plants or animals. We learned that trilobites were *animals* that lived in the *sea* and ate little animals and plants in the water. When asked how they thought trilobites moved, students answered, “They swam!” We discovered that some trilobites had eyes but some did not, and students engaged in a rich conversation about how trilobites would move without eyes. We also learned that trilobites were extinct, although relatives of the trilobites still live today.

We next discussed the crinoid fossils. Students had only found partial crinoids and so this discussion centered on how paleontologists make inferences about partial fossils by comparing them to today’s living organisms. Students debated whether or not crinoids were plants or animals. Students offered explanations such as “They have stems like plants” or “That’s not a stem, that’s a snake.” When asked, “Do you think this is a part of the fossil or the whole thing?” most students replied, “part.” We looked at a more complete crinoid and learned that crinoids were animals that live in the sea stuck to rocks. Students then learned that crinoids are alive today and were shown a picture of an extant feather star.

As an assessment, children were given a page containing two environment pictures—an aquatic beach habitat and a terrestrial forest habitat. Students were given various familiar fossil stickers (ammonites, ferns, trilobite, dinosaur, and fish skeleton) and asked to place them in the environment where they would expect to find these fossils. Over the next 10 minutes, most children appropriately demonstrated their understanding by placing the ammonites (aquatic), fish (aquatic), and dinosaurs (terrestrial) but were less able to appropriately place the trilobites (aquatic) and ferns (terrestrial). When the children incorrectly placed an organism, we directed their attention to our previous discussion of the organisms (“Do you remember when we talked about trilobites?”) and prompted them to think about specific adaptations (“What do you think these little things on the side were used for?”).

**Activity 3: Digging for Fossils With Many Parts**

We started the next lesson with a 20-minute discussion about what students already knew about dinosaurs. When asked if students thought there were any dinosaurs still left today, most said “no” while one student offered that birds are actually dinosaurs. We reviewed the idea of extinction explored earlier.

We discussed how paleontologists dig and assemble fossil dinosaur bones. With some model felt dinosaur bones (Figure 2), students were asked to assemble the bones on a felt board. Teachers asked probing questions such as, “How do you think these fit together?” and “Is there only one way they could fit together?” (to the latter, students replied “no”). We discovered that paleontologists use what they know about dinosaurs and their imaginations...
to put dinosaur skeletons together. Students observed a model felt skeleton and were asked, “Which of these pictures might show how the dinosaur looked when it was alive?” Students realized that not all pictures were possible as some were not consistent with the skeletal structure. Therefore, we could make inferences about the type of dinosaur based on the skeleton.

Students engaged in two centers this day. For the outdoor dig, children worked in research teams of six and used small shovels to find baked play dough dinosaur

<table>
<thead>
<tr>
<th>Organism</th>
<th>Picture</th>
<th>Description</th>
<th>Age of Fossil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trilobite</td>
<td></td>
<td>Extinct marine arthropods (animals) whose bodies were segmented into a head,</td>
<td>225–570 million years ago</td>
</tr>
<tr>
<td></td>
<td></td>
<td>thorax, and tail.</td>
<td></td>
</tr>
<tr>
<td>Ammonite</td>
<td></td>
<td>Extinct marine mollusks (animals) with coiled shells.</td>
<td>65–190 million years ago</td>
</tr>
<tr>
<td>Crinoid</td>
<td></td>
<td>Extinct marine echinoderms (animals) that had stem attached to a surface and</td>
<td>225–570 million years ago</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a crown of arms. Living relatives are feather stars.</td>
<td></td>
</tr>
<tr>
<td>Fish</td>
<td></td>
<td>Bony fishes with bony skeletons and scaly skin.</td>
<td>395 million years ago – present</td>
</tr>
<tr>
<td>Crab</td>
<td></td>
<td>Horseshoe crabs that lived in freshwater environments. Related to present-day</td>
<td>500 million years ago – present</td>
</tr>
<tr>
<td></td>
<td></td>
<td>horseshoe crabs.</td>
<td></td>
</tr>
<tr>
<td>Fern</td>
<td></td>
<td>True ferns (plants) that commonly grew as large trees in the Paleozoic.</td>
<td>395 million years ago – present</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Living relatives are small ferns.</td>
<td></td>
</tr>
<tr>
<td>Claw and Skeleton, Dinosaur</td>
<td></td>
<td>Reptiles (animals) that included plant- and meat-eaters and lived in a variety</td>
<td>65–225 million years ago</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of aquatic and terrestrial habitats.</td>
<td></td>
</tr>
</tbody>
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Note: Information obtained from Thompson (1995)
fossils. As teams, they collected 10 fossils at a time, assembled the bones, and drew their inferred dinosaurs. The children moved the fossils around on a table to infer the most likely whole skeleton. Figure 3 shows how one group arranged their fossils along with a drawing of an inferred dinosaur. Students spent about 10 minutes digging and 10 minutes analyzing their results. Appropriate performance on this dinosaur drawing task was exemplified by a drawing and description that included at least two found bones. The last center gave students an opportunity to practice making inferences from evidence and included paper dinosaur bones that children assembled to infer a whole animal.

We concluded this lesson with a 10-minute whole-group discussion about assembling dinosaur bones. When prompted, students answered the questions of whether everyone assembled the bones the same way (“no”) and if we are sure about how to put these dinosaurs together (“no”). Students were reminded that paleontologists have to have a lot of background knowledge and good imaginations to figure out how to put dinosaur bones together. When asked how scientists know what color to make their pictures of dinosaurs, students recognized that “bones don’t have any colors on them.” We learned that paleontologists infer that dinosaurs were probably similar in color as to today’s plants and animals.

As brief 10-minute assessment, children were given a page containing an environment with air, sky, and land depicted. They were asked to place three dinosaur stick-

Fossils on a Budget

Because the camp had a limited budget for supplies, I used art supplies to make “fake fossils” and only purchased a few items:

- Three fossil molds:
  - dinosaur-bone sandbox molds
  - a set of five plastic molds (ammonite, claw, trilobite, fossil fish skeleton, and crab)
  - a set of fossil molds through a science supply catalog (see image below)
- A bag of 100 unsorted fossils that contained a fossil key

To make fake fossils, I used plaster of paris for the indoor digs and bake-able play dough for the outdoor digs (see Internet Resource for recipes). A picture and description of these fossils are in Table 1. For safety purposes, the outdoor digs also required that children wear safety goggles. I made felt dinosaur skeletons and fossils for whole-group instruction. Finally, various assessments required stickers of fossils and dinosaurs, so I purchased stickers and made my own using clipart images printed on mailing label sheets.
Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

**3-LS4 Biological Evolution: Unity and Diversity**

www.nextgenscience.org/3ls4-biological-evolution-unity-diversity

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>Connections to Classroom Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectation listed below. Additional supporting materials/lessons/activities will be required.</td>
<td>Students collected fake fossils and examined real fossils to infer what the organisms might have looked like and the types of environments in which they might have lived.</td>
</tr>
</tbody>
</table>

**Science and Engineering Practice**

**Analyzing and Interpreting Data**

Students used observational data about fossils to infer the structures and habitats of these once living organisms.

**Disciplinary Core Idea**

**LS4.A Evidence of Common Ancestry and Diversity**

- Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments.

Children examined ammonite fossils and imagined where they lived (Activity 1), drew their proposed organism from which their fossil class originated (Activity 2), debated whether crinoid fossils were partial or complete (Activity 2), asked to place fossil stickers in the environments where they thought they lived (Activity 2), and assembled dinosaur bones to draw what the whole dinosaur might have looked like (Activity 3).

**Crosscutting Concept**

**Systems and System Models**

Students:

- examined the partial fossils and the fossils with multiple parts to make inferences about how they fit together.
- examined the fossils and made inferences about how the animal may have interacted with its environment.

**Connecting to the Common Core State Standards (NGAC and CCSSO 2010)**

**English Language Arts**

Kindergarten: Speaking and Listening Standards; Presentation of Knowledge and Ideas

5. Add drawings or other visual displays to descriptions as desired to provide additional detail.

**Mathematics**

Kindergarten: Measurement and Data

1–2. Describe and compare measurable attributes

3. Classify objects and count the number of objects in each category.
ers (aquatic, terrestrial, and avian) where they thought they belonged. Almost all students correctly placed the aquatic and avian dinosaurs, with slightly fewer correctly placing the terrestrial dinosaurs. When students incorrectly placed a dinosaur, we circulated and asked questions about particular adaptations like “Does this one have wings?” and “Where do you think we would find a dinosaur with wings?”

At the end of the week, students were given a summative assessment in the form of individual interviews during which they were asked to identify fossils—pictured and real, familiar (used in previous activities) and unfamiliar.

Several modifications could be made to suit children in different contexts. First, in a larger class, consider adding additional centers. For example, one day, we included a coloring center where children colored paleontology coloring pages. Another day, we added a center where children could explore dinosaur picture books. Second, in a group that included mostly three- and four-year-olds, expect less understanding of time (as we experienced with the three-year-olds in this class) and focus more on making observations of similarities and differences between fossils. Finally, in a group that included mostly five- and six-year-olds, use more measurements and measurement tools while comparing the fossils they found. Our one concern about this lesson was that students might think that the plaster of paris and play-dough fossils were real. We tried to point out the differences between the authentic fossils and our homemade fossils often, and we recommend doing the same.

**Conclusion**

The children showed gains in their understandings of fossils, why fossils are found in particular places, and how paleontologists construct explanations from fossil evidence. Moreover, the students and I had so much fun exploring this topic. Parents came in each day saying that their children wanted to dig in their own backyards to find fossils! Based on this experience, I contend that preschool students can engage with and learn about fossils even at this early age.

*Lisa Borgerding (ldonnell@kent.edu) is associate professor of science education and former high school biology teacher at Kent State University in Kent, Ohio.*

**References**


**Internet Resource**

Bake-able play dough for the outdoor digs  
www.cooks.com/recipe/is6nn849/make-bake-playdough.html
Interdisciplinary projects that allow students to solve real-world problems can be highly engaging and motivating. These projects give students opportunities to apply, integrate, and expand their STEM knowledge. This article describes the third-grade portion of a project that highlights the use of integrated STEM education with an engineering focus. Students were engaged in the engineering design process while the teacher provided guidance, information, and coaching. Although the teacher had an idea in mind, she chose to let students come up with the project idea through a series of informational class sessions.

The teacher facilitating this project collaborated with a kindergarten and sixth-grade colleague to create this project, which featured different problems in each of the three grades. The kindergarten class spent time learning about engineering, composting, and building individual composters. The third-grade class built machines to crush milk cartons using the engineering design cycle as a model for instruction. Meanwhile, the sixth-grade class worked on building a storage unit for the crushed milk cartons.

### Engineering Design

Engineering design requires creative problem-solving while considering constraints such as time, money, materials, and ease of use. The third-grade students used a design process that included defining a problem; generating alternatives; developing a workable design; analyzing that design; creating, testing, and improving; and coming up with a final product. As with many real engineering tasks, the design process often is not a linear route to a solution, but an iterative process. The model shown in Figure 1 of an engineering design process cycle illustrates what third-grade students were engaged in during this project.
Define the Problem

The third-grade teacher began the unit by helping her students gather information to fully define a problem and understand the constraints. Students were shown videos about composting and the use of landfills as a way to open discussion on a problem they may be able to solve (see Resources). The teacher explained that they would be studying recycling and what garbage can do to the environment. She told students they would be watching videos to help them understand the effect that humans have on the environment.

After watching the videos about the composting and landfills, students brainstormed ways they could reduce the impact of the garbage they produce at home or school. The teacher was thrilled that a student suggested exploring ways to recycle or compost the milk cartons they use at lunch, as that was the problem she intended to have them solve.

In a summer course focused on engineering education, the kindergarten, third-grade, and sixth-grade teachers at this school created a unit plan that they thought could be implemented the following year, based on the engineering design process. The summer course instructors encouraged the participants to begin with a real-world problem. This milk carton problem was the real-world problem these teachers thought the students would embrace. They chose it with the hope that all three grades would be able to learn part or all of the engineering design cycle through the exploration of a solution. By introducing students to the ideas of recycling, composting, and the excess garbage produced by the milk cartons, the third-grade teacher was hopeful that the students would realize this was a problem they could solve. Alternatively, she could have introduced the problem and done essentially the same activity through a more direct approach but her goal was for the problem to come from the students and she therefore took the chance that the students would come to the same conclusion as she had.

The teacher brought the students to the cafeteria to see all the garbage generated from lunch. She invited Bob, the custodian, into the classroom to share how the milk cartons, especially those with milk still in them, added to his workload. Students in third grade initially defined the problem as reducing the amount of garbage that Bob had to haul but, along with that solution, students realized they could compost or recycle the milk cartons. In order to solve this problem, students needed to find a way to empty and store the milk cartons for recycling or composting. This introduced a new problem because the space necessary to store the milk cartons would be great. Students then defined the real problem as developing a way to crush the milk cartons to reduce space until they could...
be composted or recycled. The third graders focused on emptying and crushing the milk cartons, while the sixth-grade class worked on creating a storage container. The kindergarteners focused on the impact of composting.

Students collected data on the number of milk cartons used per day during both snack and lunch time and graphed this data over time (see Figure 2, p. 39). They researched how long it takes various lunch items to decompose and graphed this data (see Figure 3). This information was added to the personal story of the custodian to help the students clearly define the problem and begin to create a solution.

**Generate Alternatives, Develop and Analyze Solutions**

In keeping with the engineering design process, prior to any building, students individually brainstormed solutions and used graph paper to draw potential solutions and generate alternatives. Students were provided some materials to think about as they began developing their solutions: soup cans, a potato masher, 6 in. × 3 in. wooden blocks, PVC valves, other cylindrical shapes, and rectangular prisms. Students brought in a bucket and some string to add to the materials available. Materials that were brought in needed to be student-friendly and have a very low (or no) risk of injury to the students. Beyond material constraints, it was identified that ALL students, from kindergarten to eighth grade, needed to be able to safely use the machine to crush their milk cartons. No models were created at this point; this was just a brainstorming phase to generate alternatives and develop solutions.

Students were then placed into heterogeneous groups of three or four, with both boys and girls in each group, where they shared individual solutions, brainstormed beyond those solutions, and synthesized an optimal solution. The teacher remained a facilitator and let the students decide which solutions were reasonable without trying to lead them down a set path. They analyzed their own solution, as a group, in order to choose one to create.

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**FIGURE 3.**

Amount of time it takes various lunch items to decompose.

*By introducing students to the ideas of recycling, composting, and the excess garbage produced by the milk cartons, the third-grade teacher was hopeful that the students would realize this was a problem they could solve.*
Create, Test, and Improve

Students moved into the final prototyping phase in their small groups. Prototypes were created and then tested—first by third graders and then by kindergarteners—with the requirements that the machine could easily crush the milk carton and kindergarteners were able to use the machine. The teacher was careful to monitor the use of the prototypes during creation and testing to eliminate any safety concerns. Goggles were worn to avoid injury. Critical to the learning process was the teacher-facilitated discussion on possible improvements and steps needed for redesign. Questions students were asked included: How easy is it to use? How effective is it? How quick is it? Are there improvements that can be made? Students then made improvements and prepared to present to the class.

Final Product

The final product of each group was then presented to the class and put up for a vote on the best choice to fit the needs of the problem. To be the most successful project, the carton crusher needed to be effective, safe, quick, and inexpensive. The winning design (by class vote) ended up being the simplest: a pail to pour milk in followed by a block of wood to crush the milk carton in a pan to prevent splashing (see Figure 4).

This solution, however, created a new problem, as so often happens in the real world. The kindergarten class was unable to crush their own cartons with the machine. So, how did the students solve this new problem? They agreed that the older students would simply help them crush their cartons while the classroom teachers supervised the crushing. This “non-engineering” solution served as an important lesson in the need for the “4Cs”: communication, collaboration, critical thinking, and creativity.

Connections

The teacher in this classroom led a student-driven engineering design challenge that integrated science, engineering, and mathematics as well as other content areas and skills. Students were actively engaged in groups, sketched possible problem solutions, voted on designs, and wrote reflections on the process. Students were interviewed after the final product had been chosen and asked, “Will you please tell me about your engineering project?” Students were articulate when describing the process they went...
through and clearly stated environmental and practical reasons for doing this project.

An unexpected element that surfaced during the interviews was the students’ compassion for the custodian and the awareness of the amount of garbage they were generating from the milk cartons. A student explained:

“We tested how much garbage we throw away a day and we got somewhere around two hundred pounds I think. And Bob says it’s really heavy. Each day we recycle milk cartons, we’ll reduce about 15 pounds on each bag, so it’ll be lighter for Bob.”

Implementing Your Own Challenge

This was the students’ first introduction to engineering and integrated STEM. Every student interviewed (about half the class) responded positively to the challenge, stated they would like to do another challenge, explained how actively engaged they were, and agreed that having failures was perfectly acceptable. This project helped further these students’ understanding of an engineering design cycle, created opportunities for collaboration, and encouraged them to solve a problem they felt was important.

As teachers plan for their own real-world engineering challenge, there are some important things to consider. First, can students help define the problem? If they can, what information do they need to be able to do so? Next, what are the constraints? Will you allow them to use unlimited materials, choose what they use, or attach a cost to each material used? How can you highlight engineering design throughout the challenge? For this challenge, success was measured through the completion of a solution, but teachers can consider other formative assessments along the way to ensure active student engagement throughout the project. It is important to include check-in points throughout the activity to monitor progress of the individuals as well as the groups. The instructor assessed students’ participation in activities through informal observation based on participation, used a KWL chart (Ogle 1986) to assess student understanding at various points in the process (what do you Know, what do you Want to know, and what did you Learn?), and used classroom discussion, including student answers to verbal questions, as a way to check progress and understanding. The teacher collected their graphs, observed group discussion, and carefully monitored student engagement. In addition to informal assessments, a more formal rubric could be used to give students feedback based on the engineering design process used (see NSTA Connection).

One piece of this integrated work that could be improved was taking time to explicitly point out the connections between different content areas. When students in the interviews were asked if they did mathematics, most responded that they did not, even though they mentioned the graphing and calculations they had to do. The teacher agreed that next time she would like to spend time discussing the different content necessary to complete a problem like this. Making connections is a key component as we look to encourage all students to learn STEM concepts in the classroom. ■

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References


Resources


Woolhouse, C. The Three Rs Reduce Reuse Recycle. www.youtube.com/watch?v=wtOEZ9Nkeqk.

NSTA Connection

Visit www.nsta.org/sc1507 for the rubric.
### Connecting to the Next Generation Science Standards (NGSS Lead States 2013)

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>Connections to Classroom Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectation listed below. Additional supporting materials/lessons/activities will be required.</strong></td>
<td>Students build models to observe and test the ability of the mechanism and materials to provide the crushing solution.</td>
</tr>
<tr>
<td><strong>2-PS1-2 Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.</strong></td>
<td></td>
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</tbody>
</table>

### Science and Engineering Practices

<table>
<thead>
<tr>
<th>Planning and Carrying Out Investigations</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>• plan simple investigations of materials and mechanisms available to solve the problem.</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>• construct models of solutions.</td>
</tr>
<tr>
<td>Engaging in Argument From Evidence</td>
<td>• collaboratively plan and conduct and investigate possible solutions and collect data.</td>
</tr>
<tr>
<td></td>
<td>• analyze data collected from testing to determine if the materials and mechanism solve the crushing problem.</td>
</tr>
<tr>
<td></td>
<td>• construct explanations of which materials and mechanisms best solve the problem.</td>
</tr>
<tr>
<td></td>
<td>• engage in argument from evidence.</td>
</tr>
</tbody>
</table>

### Disciplinary Core Idea

<table>
<thead>
<tr>
<th>PS1.A Structure and Properties of Matter</th>
<th>Students evaluate the materials and mechanisms available to solve the problem.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Different properties are suited to different purposes.</td>
<td></td>
</tr>
<tr>
<td>• A great variety of objects can be built up from a small set of pieces.</td>
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</tr>
</tbody>
</table>

### Crosscutting Concepts

<table>
<thead>
<tr>
<th>Cause and Effect</th>
<th>Students use models to test crushing performance of the models and in turn gather evidence to support or refute claims.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy and Matter</td>
<td>Students break milk cartons into smaller pieces to change the volume and surface area of the carton.</td>
</tr>
</tbody>
</table>

### Connecting to the Common Core State Standards (NGAC and CCSSO 2010)

**CCSS.Math.Content.3.MD.B.3**

Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step “how many more” and “how many less” problems using information presented in scaled bar graphs.

FAMILIES LEARNING TOGETHER

An elementary STEM-focused event brings students and families together.

By Sarah MacDonald and Matthew Maurer
The outreach program of Robert Morris University consistently works to keep STEM current and collaborative for K–12 students in the Pittsburgh region. All of our STEM events engage students in a hands-on, inquiry-based environment while fostering mentor-student relationships that permit our student participants opportunities to engage with professionals during and after each event. We believe STEM includes more than just conceptual learning and should contain an innovative hands-on component.

We have begun offering a number of elementary-based STEM programs through our school due to a high demand from parents for events within the K–4 grade levels. To address this need from the community, we recently offered our own Elementary Family STEM Night. This event featured STEM skills taught through hands-on learning, integrated technology, art, and design. Families were engaged in activities facilitated by experienced faculty, students, and industry professionals.

Why Include Families in STEM?

In recent years, there has been a distinct shift in the science preparation of students at the K–12 levels. We have seen the implementation of the Next Generation Science Standards (NGSS Lead States 2013), which include a strong STEM-based focus to all K–12 science curricula. Beginning with early elementary grades, students are being asked to learn in an integrated manner, specifically with STEM concepts. In the early pages of the Next Generation Science Standards the following conceptual shifts are among the listed: “The NGSS focuses on a deeper understanding and application of content” and “Science and engineering are integrated in science education from K–12,” (NGSS Lead States 2013, p. xix). The focus of Family STEM Night was to illustrate how STEM can be fun and exciting for K–4 students. Through the use of selected hands-on activities, families were given the opportunity to engage in science and engineering content in ways that integrated activities from separate disciplines into one event. This contemporary approach is new and challenging for both teachers and students. According to Heil, Amorose, Gurnee, and Harrison, “By showing an interest in science and making time to explore ideas and conduct simple investigations, parents can have a positive influence on children who may otherwise decide that science is too hard, too abstract, or too boring” (1999, p.12).

Based on models by Heil and his associates, Elementary Family STEM Night helped to facilitate the shift to a more contemporary approach by offering a novel opportunity for elementary school students to engage in hands-on STEM-based activities with support of their parents and families.

Our STEM Activities

Elementary Family STEM Night focused on introducing STEM to students in grades K–4. All students participated in the same activities. Students’ prior knowledge was assessed by each station’s facilitator as part of their discussions. Adjustments were made by activity facilitators if students seemed advanced or needed more assistance. Each station activity was structured so that facilitators could tailor the activities to meet each student’s needs. We gathered STEM professionals, faculty, and students together to have an evening of learning, excitement, and exploration. Over 150 students and their family members attended the two-hour event on a drop-in basis. Attendees participated in an active learning environment that engaged them in higher-order thinking skills, problem solving, design, and data analysis.

According to Heil, Amorose, Gurnee, and Harrison, “Research in recent years has clearly pointed out that children who do activities with their parents, build close relationships, and learn together will be happier, more self-confident in their own learning, and demonstrate a high level of emotional well-being” (1999, pp. 7–8). To facilitate this, the intended atmosphere of the event was for families to learn at their own pace. We wanted families to realize that STEM learning does not have to be done in a traditional classroom setting. Each family was given a program including basic content and information for each station and spaces were made available for families to sit and discuss the activities with the children.

Most activity stations had a facilitator to guide the activity and explain the STEM concepts behind it. For stand-alone stations (those without a facilitator), we provided instruction sheets that explained the importance of the activity, the STEM concepts, and a guide on how to
complete the activity. Some stations did not have facilitators due to staffing issues, materials being self-explanatory, and by design, permitting students to explore, learn, and discuss activities as a family unit. Although we found the facilitated activities offered a better overall hands-on experience, the stand-alone activities had positive aspects as well, such as permitting families to learn at their own pace and giving parents the chance to lead the STEM discussions with their children, truly making it a family learning experience. For a list of activities, see Table 1. A more in-depth review of one of the activities—the gummy bear launch—is available online (see NSTA Connection).

We used the university cafeteria space, which is proportional in size to most school cafeterias. This event was different from a traditional elementary science night because it was held at a university and in many cases in-

<table>
<thead>
<tr>
<th>Activity</th>
<th>NGSS Performance Expectation</th>
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</thead>
<tbody>
<tr>
<td><strong>3-D Printer</strong></td>
<td>K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.</td>
</tr>
<tr>
<td>Students see a 3-D printer create toys. Students are given background into why 3-D printers are important to engineering. They are able to see the printer working up close and hold the materials before they go through the printer and then after they’re printed. Facilitated Station.</td>
<td></td>
</tr>
<tr>
<td><strong>Roman Arch</strong></td>
<td>K-2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.</td>
</tr>
<tr>
<td>Students build a Roman arch using the provided kit, which demonstrates static equilibrium and the resolution of forces in clear fashion. Non-facilitated Station.</td>
<td></td>
</tr>
<tr>
<td><strong>Human Biology and You</strong></td>
<td>3-LS1-1 Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death.</td>
</tr>
<tr>
<td>Students observe and handle anatomical pieces. Students learn about basic anatomical structures and aspects of physiology. Non-facilitated station.</td>
<td></td>
</tr>
<tr>
<td><strong>Nutrition</strong></td>
<td>K-ESS3-1 Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live.</td>
</tr>
<tr>
<td>Students observe and handle nutrition pieces while matching sugar contents to various food models. Students are engaged in aspects of nutrition and health, including: observing and handling food models while matching their sugar contents, observing and picking up 1 lb and 5 lb fat models, reading nutrition labels and testing their balance on a Spooner board. Non-facilitated station.</td>
<td></td>
</tr>
<tr>
<td><strong>How Much Is 293? (Adapted from Heil et al. 1999)</strong></td>
<td>2-PS1-1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.</td>
</tr>
<tr>
<td>Students attempt to pick out 293 unpopped popcorn kernels from a container. They then attempt to design and build a container to efficiently hold 293 popped kernels. Facilitated Station.</td>
<td></td>
</tr>
<tr>
<td><strong>Spectral Diffraction</strong></td>
<td>K-2 ETS1-3 Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.</td>
</tr>
<tr>
<td>Students learn about the spectral properties of light. These activities are best done in a low-light or dark setting. Facilitated station.</td>
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TABLE 1.
Activities list and performance expectations.
For the purpose of simplification, only the performance expectation is included here. The materials/lessons/activities outlined here are just one step toward reaching the performance expectations listed below. Additional supporting materials/lessons/activities will be required.
Families Learning Together

Involved facilitated discussion/instruction from university STEM faculty. The content focus was also broader than just science, including some aspect of all STEM disciplines in each activity. For example, at our 3-D printer and gummy bear launch activity stations, the main focus was engineering and technology, the human biology activity focused on science, and the “How much is 293?” activity focused on mathematics.

All participants were required to sign an RMU Liability/Release Form, which stated there may be some risk associated with activities done at Family STEM Night. Any additional or specific safety issues were discussed by activity facilitators before the start of any experiments. Safety was a primary concern in all of our activity stations. Activities were chosen that minimized safety risks and no protective equipment was needed for any of the activities performed.

Assessing Effectiveness

It was our observation that this event was truly all-encompassing for each family—parents, students, and siblings all learned together in an engaging, active manner. During the event, families were engaged at each station, discussing possible solutions and questioning/answering why activities and experiments turned out the way they did. At stand-alone stations, families spent time analyzing the activity, attempting to complete the activity, and discussing the outcomes. Many families also took the opportunity to sit together at tables and discuss their creations and the outcomes of the activities. There were many instances of collaborative problem solving, redesigning, and group accomplishment when the families successfully finished each task.

Overall, over 150 people attended our event, which was more than originally anticipated. Due to the nature of this event and the context for which the families were learning collaboratively, formalized assessment of learning was extremely difficult. However, we did ask all students and parents to complete anonymous online pre- and post-event surveys (approved by our university IRB), which gathered demographic information, reason for attendance, and basic questions to assess acquired knowledge of STEM and satisfaction with participation (see NSTA Connection for a copy of the survey). The survey did not provide an assessment of learning for each individual activity, a definite limitation of our data-gathering process. While we have provided suggested assessment measures for each activity online (see NSTA Connection), one of our goals when offering this event again will be to implement more formalized assessment measures at each activity station so that the learning impact of each activity may be assessed individually.

Our overarching goal for the event was to permit students and families to collaboratively work to solve problems and design solutions to specific STEM tasks. The most important STEM “take-away” to us was: Were they able to accomplish the STEM tasks successfully? This included completion of a variety of products specific to the activities, such as creating a container for the 293 kernels of popcorn, creating a catapult for the gummy bear launch, or constructing the Roman arch. Through our own observation, including those of our participating facilitators, we observed families directly and provided adm-

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ditional discussion, content, and direction when it seemed that the STEM concepts of a particular task were eluding them. Collectively these observations displayed that the majority of participating families were able to complete the tasks of each station successfully, either through creating a product or engaging in a discussion about the intended STEM concept.

Planning and Implementation

Based on our experience with this event, we recommend the following to implement an Elementary Family STEM Night at your school.

1. **Scale.** This event can easily be transferred to many elementary schools. It can be held as a classroom activity or as a large school event held in a cafeteria or gymnasium. It can be as large or small as your school space allows.

2. **Cost.** STEM does not need to be expensive to be exciting. We decided to make the event free so that all students would have the chance to engage in a novel learning experience without the burden of extra costs. As such, we intentionally chose activities that were as cost effective as possible, simple, and readily available. For example, in the gummy bear launch activity, limited supplies were purchased. For technical items, such as the 3-D printer, schools can partner with local universities or businesses to bring in their expertise and equipment.

3. **Recruitment.** We sent e-mails to a database of local teachers and parents. We also mailed out flyers to regional schools, which included lower socioeconomic areas.

4. **Direction.** Before the event, packets were mailed and e-mails sent to parents with directions to the event, food that will be served, and liability/release forms. At the start of the event, each family received a bag containing a detailed program of each activity station, raffle tickets, and giveaways. We had university students check in attending families, collect forms, hand out bags, and give families an introduction to how the event was structured and how they should proceed through the event.

5. **Food.** Since the event was held from 4 p.m.–6 p.m., we offered a small buffet of snacks to families. All of the snacks were intentionally healthy to go along with our Nutrition and Health activity station. We also made sure to clearly post each snack’s ingredients. Food provided by our campus food service did not include anything that was a potentially allergy concern, as identified by parents in advance. All allergies were listed on the registration form that each family had to send in to complete event registration.

6. **Stations.** Activity stations were set up throughout
Families Learning Together

Students explored human anatomy with models.

the cafeteria space. Each station was clearly marked with a sign. We tried our best to divide off each station so it had its own area. Stations without a facilitator had detailed descriptions and guides on how to complete the activity. Station facilitators guided families through their activities, explained the STEM concepts behind the activity, and answered any questions families had in regards to the activity or STEM.

7. Activities. Our activities were chosen based on resources listed in the book Family Science (Heil et al. 1999), as well as input from our STEM faculty members and planning team.

Conclusion

We learned several lessons from this event:

• STEM does not have to be expensive to be exciting.

• Formalized assessment can be difficult in a public setting; this is an area we will develop more thoroughly for future events.

• Staffing is important; in the future we will have facilitators at all stations to guide learning and exploration.

• In the future, we will make sure there is a list of event expectations for parents and students to ensure cleanliness, clean-up, and respectful use of equipment.

Despite some of these hurdles, we feel that Elementary Family STEM Night was a success and intend to make it an annual outreach event. We observed many families having fun while learning together. This was our intent—to make STEM an enjoyable and accessible discipline for all. During our event we purposely made our STEM activities identifiable to students and their family members in hopes that it would cause them to associate everyday tasks and fun experiments with STEM. Changing the way STEM is perceived helps keep it current, creative, and career-focused. These elementary school students will be the future of the STEM field. We feel it best to start engaging them and getting them excited at a young age. What better way to do this than alongside those they trust most—their family members?

Sarah MacDonald (macdonald@rmu.edu) is a SEMS Outreach Manager, and Matthew Maurer is a Co-Director of the School of Engineering, Mathematics, and Science Research and Outreach Center at Robert Morris University in Moon Township, Pennsylvania.

References


NSTA Connection

For more details about the gummy bear launch, the NGSS connections for the catapult activity, suggested assessment measures for each activity, and the pre- and post-event surveys, visit www.nsta.org/sc1507.
In kindergarten, we start September with a “study of color”—red day, yellow day, blue day, and so on. For a couple of weeks, the children and teachers all wear the color of that day. Activities in the classroom center around the colors we study. As part of the color study, I have on display in our science area various items from nature that add other sensory experiences to color, such as texture and smell—a whole coconut with its rough brown husk, some smooth black river stones, some brilliant yellow lemons with their knobby skin and tangy scent. The children can see, touch, and smell the various colors.
A few years ago, as my students were exploring these items, I heard conversations about taste, especially about the lemons. Some had tasted lemons before and couldn’t say enough about how delicious they were; others were not sure if they had or had not tried them; some were sure they would taste terrible; and some talked about lemonade. While listening to all this talk, it struck me that I was hearing an opportunity to introduce investigation.

Inspired by Color

I announced to the children that I was cutting up the lemon so they could smell and taste the inside. Some immediately backed away from me in nervousness and others let out cries of delight. As I cut up the lemon into slices and offered each child a slice, I asked each to tell me whether the lemon was sweet, sour, or a little bit of both. Those who had no desire to taste the lemon did not have to. I noted the children’s responses using dots, creating a graph (see Figure 1). Throughout the rest of the morning, I had repeat requests for seconds and thirds of lemon and there was a lot of chatter about the way it tasted and the way people looked as they tasted it (including me!). Some who had not tasted it the first time decided they wanted to try it after all. I ended up taking down votes for “liked it,” “did not like it,” and “not sure” on another graph.

During story time, I shared the graphs I had made and the children almost immediately started identifying whether more children thought the lemon was sour or sweet. They also noted that “liked it” got the most votes and “not sure” got the least. We counted the votes together and wrote the totals down in the corresponding columns.

Because of the palpable energy around the lemon tasting and the richness of the discussion following it, I de-

Taste Testing on a Budget

For each taste test, you need to have only enough for everyone to get a small bite or sip. Sometimes, depending on the item, you will have enough for seconds; other times, you will not. I am fortunate that my school’s budget allows for me to do a few taste tests a week. This enables us to really explore the letter sounds and experience a variety of tastes (i.e., cilantro, cranberries, and chamomile for C week). It also allows for opportunities to taste different varieties of the same fruit or vegetable.

If budget constraints are a factor, consider the following suggestions:

1. Limit it to one or two taste tests per week.
2. Ask parents to rotate, sending in items for each letter.
3. Check with your PTA to see if they can fund the taste tests.
4. Talk to your local grocery store. They may be interested in partnering with your class and donating taste tests free for the year (practically free publicity!).

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FIGURE 2.
Curriculum web.

Taste Test Learning Goals

Math
- Recording, counting, and comparing votes
- Analyzing and interpreting data
- Learning concepts of more, less, most, and least and comparing quantities
- Graphing results using various representations (bar graph, Venn diagram, and pie graph)
- Using different methods of recording (tallying and writing)

Science
- Classifying similarities and differences in various foods
- Differentiating opinion from fact
- Analyzing and interpreting data
- Conducting decomposition experiments; investigating variability
- Cooking/freezing foods and observing/articulating changes
- Identifying food as a source of life for all living things
- Understanding that a region’s weather can determine the kinds of food available

Literacy
- Building new and “juicy” vocabulary
- Writing about taste tests in journals
- Listening to books on cooking, cuisine, cultures, and gardening
- Making mini books about taste tests
- Reading the graphs and identifying where to vote
- Extending opportunities for letter-sound recognition

Social Studies
- Trying new foods = risk-taking/stepping out of our comfort zone
- Learning where different foods come from
- Respecting differences in opinion
- Mapping the foods’ origins
- Creating connections for children from that part of the world
- Harvesting and tasting what we grow in our garden

decided to repeat the experience the next day for purple day. I brought in a purple cabbage, a vegetable I thought most of the children would not be familiar with. I chopped some of the raw cabbage into thin slices and set it out on a table for tasting. It was the first thing children noticed as they walked through the door in their various purple paraphernalia! There was excitement, curiosity, and—yes—trepidation on some of the faces. We tried it raw, described how it tasted (crunchy, bland, juicy, like salad), filled out another graph, and then wondered whether the taste would change if we cooked it. Of course, when we did, the cabbage lost its crunchiness and the chil-
Eating the Alphabet

Children noted this as they described the taste. It was an easy way to highlight the core idea in physical science that heating can change a substance and that in this case, it was also not reversible.

Reflecting on Curricular Connections

As I reflected on my day, it dawned on me that through each taste test activity, I had been able to teach and weave together some math, literacy, social studies, and science concepts. If I continued providing similar experiences, the opportunities for building on this integration and creating a spiraled learning process were tremendous. I decided to use a backward design model and think about the following question: What science, math, literacy, and social studies objectives of our kindergarten curriculum would these taste tests help to achieve? What could the tangible and the intangible learning be? I used a curriculum web (see Figure 2) to illustrate how I answered this question. Diving even deeper into the Next Generation Science Standards (NGSS Lead States 2013), I realized that I would be able to highlight

Our Taste Tests A to Z

Here’s a sample of what my kindergartners tasted this year with each letter of the alphabet (I only offered fruits, vegetables, and dairy products—no meat or poultry).

A  Asiago cheese, arugula, apricots, apple pear
B  buttermilk, brussels sprouts, black beans, banana chips
C  cranberries, coconut, cilantro, chamomile
D  dill, dates, dragon fruit
E  eggplant, edamame
F  figs, fennel, feta cheese
G  guava juice, ginger cubes, gouda
H  horseradish cheese, hummus
I  iced tea, iceberg lettuce, iddiappam
J  jackfruit, jelly (mint), juice of carrot
K  kefir, kiwi, kale
L  lychee juice, leeks, limeade
M  mango (dried), mango chutney, mushrooms (enoki)
N  navel oranges, naan, New England cheddar
O  okra, olives, olive oil
P  persimmon, papaya juice, pomegranate, parsley
Q  quail eggs, loquat, quinoa
R  red chard, radish, radicchio
S  starfruit, spinach, snow pea shoots, seaweed
T  tamarind, tzatziki, turnips
U  udon noodles, ugli fruit
V  vegetable juice, vinaigrette
W  wild rice, water chestnuts, wasabi peas
X  flax seeds (ground and not ground)
Y  yogurt (plain), yams, yeast
Z  zucchini, zima tomatoes, lemon zest

Safety

Check for student allergies with the school nurse before eating in the classroom. Provide parents with written notification prior to the activity and instruct them to let the teacher know if there are any health issues they might be aware of relative to food tasting or eating. Cover tables with paper and use disposable dishes. Make sure fresh vegetables and fruits are thoroughly scrubbed and washed to lower or prevent exposure to pesticide or microbes. Try to secure sugar-free and preservative-free canned foods. Be sure to monitor students for proper hand washing, and follow your school or district guidelines for eating in the classroom. Supervise tasting/eating in case of choking or other emergency. Once the activity is completed, clean up all food on tables and the floor to discourage visitations by insects, rodents, and so on. Do not allow food to stay out in the classroom overnight. Always place it in a refrigerator or other secure location as appropriate. Make sure the trash receptacle is emptied and cleaned at the end of each day.
It is important to highlight that while the taste testing is not a traditional “science” activity, the specific investigations that arise out of these taste tests are very deliberately linked to some disciplinary core ideas, science practices, and crosscutting concepts recommended by the NGSS, although by no means confined to them. The taste tests are an ongoing, year-round activity built into our classroom morning routine a few times a week. As represented by the curriculum web (Figure 2, p. 52), this activity encourages strong connections between science, math, and literacy, which is actively recommended by NGSS. It does not take the place of other investigations that can teach the same conceptual understandings and practices in science but instead is another entry point for students to experience science through a familiar activity. In my fifth year of using taste tests in the classroom, I have found them to be effective in encouraging children to “wonder”—to ask questions about the “where,” “how,” and “what-ifs” of the foods we taste.

The Daily Routine

We set up the taste tests at the same table every morning. The table also had labels for the food we would taste that day and a graph we printed out and placed near the food. Children had time to taste the food during a period we call Choice Time, when they are trickling into the classroom, unpacking, checking in with teachers, getting their morning snack, and getting ready to start the school day. By the time we start the morning meeting, everyone is expected to have tried the taste test and filled out the graph. For many months, I created the graphs and each time a new graph was introduced, I modeled for the children how to fill it out. My students very quickly became familiar with my expectations and errors in recording became opportunities for discussion about accurate representation of information and data collection. As students became familiar with the different graphs, I started asking for volunteers to create graphs of their choice to represent the data to be collected. Discussions about the taste test, the information collected on the graph, and any investigations we may want to conduct on a taste test always took place during our morning meeting, immediately after Choice Time.
Setting Up for Success

As I integrated the taste tests into our classroom routines, I struggled with whether or not to make them optional. My first thought was that everyone needed to try it in order to vote, if only to encourage them to step out of their comfort zone. However, I also recognized that some children needed more time than others to find their way out of any discomfort. I compromised by making it optional in the first few weeks and then gradually increasing expectations for everyone. This allowed for students to initiate the “risk-taking” at their own pace while giving me time to get to know the students who were not tasting and figuring out ways to encourage them to do so without making it an ordeal. In order to create a sense of safe community, children also needed to feel free to truly express their opinion. I found that the most important way to do this was to lay the groundwork for differences of opinion and remove the notion that a particular response “won” when it had the most votes. Emphasizing that it was okay not to like a taste test and modeling how to do a taste test was crucial for laying this groundwork. My assistant and I spent the first couple of weeks showing children how to taste and describe what they are tasting, sometimes modeling why we like a particular flavor and other times why we do not. We have also, at times, deliberately modeled hesitation with a taste test, citing unfamiliarity, so that our students can see our uncertainty and our willingness to overcome it. We gave the children firm guidelines:

1. Take a little nibble.
2. Describe the taste to a teacher or classmate without using the word “yuck.”
3. Finish it if you like it. Put it in the food scraps bucket if you do not.
4. Vote your opinion.

Interestingly, I found that some children who were hesitant or resistant to the taste tests would sometimes have hesitancies in other areas of the curriculum, whether it was social, physical, or academic. Encouraging them to cross that threshold to try a new food encouraged some risk-taking in other areas as well. See the tasting table setup in Figure 3.

Investigations in Science

When children compared the various foods we tasted and classified them, they were beginning to look for observable similarities and differences that formed the basis of our classification system. We spoke about the different kinds of citruses we tasted and how they are similar or different from each other. We have also, at times, deliberately modeled hesitation with a taste test, citing unfamiliarity, so that our students can see our uncertainty and our willingness to overcome it. We gave the children firm guidelines:

1. Take a little nibble.
2. Describe the taste to a teacher or classmate without using the word “yuck.”
3. Finish it if you like it. Put it in the food scraps bucket if you do not.
4. Vote your opinion.

Interestingly, I found that some children who were hesitant or resistant to the taste tests would sometimes have hesitancies in other areas of the curriculum, whether it was social, physical, or academic. Encouraging them to cross that threshold to try a new food encouraged some risk-taking in other areas as well. See the tasting table setup in Figure 3.

Students tally up their classmates’ preferences.
ion (“I like the taste of this food”) versus fact (“It is a citrus fruit”). During group meetings, we charted out what is an opinion about a food we taste and what is a fact. This helped us assess which students had grasped the difference and which were still learning to differentiate the two. We compared and contrasted our taste test data with our weather graph discussing how the information on our weather graph is based on daily factual observations while the information collected for our taste tests is based on likes and dislikes, and are thus opinions. Other data collection activities, such as when children record the weekly growth of paperwhite bulbs, offer the opportunity to compare and contrast objective and subjective data. Remind students they should never eat bulbs used in the classroom. Students also started observing and articulating changes to the food when we cooked it (for example, when we cooked fresh cranberries or sautéed leeks), froze it (when we froze apple cider and grape juice into pops), or unfroze it (when we left a cider pop out to confirm that it would melt back into liquid apple cider). We learned that heating or cooling a substance can cause observable changes, some of which are reversible (freezing and unfreezing the apple cider) and some of which are not (cooked cranberries).

Students were encouraged to start formulating questions about how a fruit or vegetable could be further investigated. Depending on the foods we taste and the questions students have, these investigations can vary year to year. Once, we decided to make raisins by leaving leftover grapes on a sunny ledge and observing the process of change as well as noting the time it took for the change to occur.

In the beginning of the year, mathematical thinking through taste tests focused on one-to-one correspondence and conversations around quantity. Is there one vote for every student? Which got the most votes? Which got the least? As
the children gained familiarity with our taste test station and the procedures, I started introducing them to different kinds of graphs for recording the votes: first bar graphs, then Venn diagrams, pie charts, and surveys. We discussed how many more or fewer votes a response got as compared to another. The use of math language became a norm in our conversations as the children identified and interpreted the information the graphs give us. The graphs were added every week to the class Taste Test Graph Book (Figure 4), which became a favorite to look through at rest or reading time.

I offered my students different ways of recording information; at times, they recorded their votes directly onto a graph that I had created. At other times, unifix cubes stacked up or craft sticks in voting cans were the method. Students began exploring various ways to represent this information on paper and some started independently taking surveys or recording information about other things they were interested in. For example, we had one student conduct a survey on a favorite color and collate the information herself into a bar graph, while several decided to create their own graphs for our watercress taste test (see Figure 5).

Assessing for Understanding

At our daily morning meetings, my assistant and I noted how students answered the questions we posed about the taste test and related investigations, which students volunteered to make the graphs, as well as any questions students asked. Because the activity encompasses science, math, and literacy and happens almost daily, we were consistently able to gauge a number of understandings in each of these disciplines during these “turn and talk” partner conversations during morning meetings. Therefore much of the assessment was formative; it involved listening to what students said and asking them for the “why” of their responses to get to their underlying understanding, whether it was in science, math, or literacy. Science journal entries about the taste test investigations also gave us a sense of the thinking that students were engaging in and informed our teaching.

Building Community

The experience of tasting different foods together and using it as an anchor for various investigations did more than provide my students with numerous opportunities for learning science concepts and practices (as well as concepts in math, literacy, and social studies). It was also a wonderful community-building experience. Because I introduced a wide variety of foods from all over the world, my students had the opportunity to experience tastes beyond their day-to-day experiences (see the Our Taste Tests A to Z sidebar). In doing so, I also found that I could create connections for children whose families have come from that part of the world and who eat these foods on a regular basis. Living in a populous, multicultural city such as ours, my students were already familiar with a wide range of cuisines and took much of it for granted. Learning that the food originates elsewhere and needs to be transported here was an added dimension to their knowledge of the food and provided an introduction to our global connectedness and the technologies that make this possible. So go ahead, eat the alphabet—you will be surprised at the many things that you and your students can learn from the experience!

Jyoti Gopal (jgopal@riverdale.edu) is a kindergarten teacher at Riverdale Country School in the Bronx, New York City.

References


Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

### 2-PS1 Matter and Its Interactions

www.nextgenscience.org/2ps1-matter-interactions

<table>
<thead>
<tr>
<th>Performance Expectations</th>
<th>Connections to Classroom Activity</th>
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<tbody>
<tr>
<td>The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectations listed below. Additional supporting materials/lessons/activities will be required.</td>
<td>Students compare and contrast their investigation of the decomposition of various fruits and vegetables. Students cook various foods and freeze/unfreeze various liquids we taste throughout the year and use these experiences to explain reversible versus irreversible changes.</td>
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<table>
<thead>
<tr>
<th>Performance Expectations</th>
<th>Connections to Classroom Activity</th>
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<tbody>
<tr>
<td>2-PS1-1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.</td>
<td>Students compare and contrast their investigation of the decomposition of various fruits and vegetables. Students cook various foods and freeze/unfreeze various liquids we taste throughout the year and use these experiences to explain reversible versus irreversible changes.</td>
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<th>Performance Expectations</th>
<th>Connections to Classroom Activity</th>
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<tbody>
<tr>
<td>2-PS1-4 Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.</td>
<td>Students compare and contrast their investigation of the decomposition of various fruits and vegetables. Students cook various foods and freeze/unfreeze various liquids we taste throughout the year and use these experiences to explain reversible versus irreversible changes.</td>
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### Science and Engineering Practices

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<tr>
<th>Science and Engineering Practices</th>
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<tbody>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>Students</td>
</tr>
<tr>
<td>Using Mathematics and Computational Thinking</td>
<td>• Observe, record and communicate changes in the foods they are investigating, through science journal entries and “turn and talk” conversations.</td>
</tr>
<tr>
<td>Obtaining and Evaluating Information</td>
<td>• Use various kinds of graphs to record information about the foods we taste.</td>
</tr>
<tr>
<td>Students compare and contrast their investigation of the decomposition of various fruits and vegetables. Students cook various foods and freeze/unfreeze various liquids we taste throughout the year and use these experiences to explain reversible versus irreversible changes.</td>
<td>• Use mathematical language to share their understanding of the data collected in the graphs.</td>
</tr>
<tr>
<td>Students identify taste tests as plant products or animal products, as harvested directly from nature or created with human intervention (as in a cooked food). Students conduct cooking investigations (fresh cranberries into cranberry sauce is one example) as well as freezing investigations (freezing and unfreezing apple cider and grape juice is one example) to observe changes that can happen to the foods as they are heated or cooled.</td>
<td>• Differentiate between opinion and fact.</td>
</tr>
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### Disciplinary Core Ideas

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<tr>
<th>Disciplinary Core Ideas</th>
<th>Connections to Classroom Activity</th>
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<tbody>
<tr>
<td>PS1.A Structure and Properties of Matter</td>
<td>Students identify taste tests as plant products or animal products, as harvested directly from nature or created with human intervention (as in a cooked food). Students conduct cooking investigations (fresh cranberries into cranberry sauce is one example) as well as freezing investigations (freezing and unfreezing apple cider and grape juice is one example) to observe changes that can happen to the foods as they are heated or cooled.</td>
</tr>
<tr>
<td>• Different kinds of matter exist and many of them can be either solid or liquid depending on temperature. Matter can be described and classified by its observable properties.</td>
<td>Students identify taste tests as plant products or animal products, as harvested directly from nature or created with human intervention (as in a cooked food). Students conduct cooking investigations (fresh cranberries into cranberry sauce is one example) as well as freezing investigations (freezing and unfreezing apple cider and grape juice is one example) to observe changes that can happen to the foods as they are heated or cooled.</td>
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<tr>
<td>PS1.B Chemical Reactions</td>
<td>Students identify taste tests as plant products or animal products, as harvested directly from nature or created with human intervention (as in a cooked food). Students conduct cooking investigations (fresh cranberries into cranberry sauce is one example) as well as freezing investigations (freezing and unfreezing apple cider and grape juice is one example) to observe changes that can happen to the foods as they are heated or cooled.</td>
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<tr>
<td>• Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible but sometimes not</td>
<td>Students identify taste tests as plant products or animal products, as harvested directly from nature or created with human intervention (as in a cooked food). Students conduct cooking investigations (fresh cranberries into cranberry sauce is one example) as well as freezing investigations (freezing and unfreezing apple cider and grape juice is one example) to observe changes that can happen to the foods as they are heated or cooled.</td>
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### Crosscutting Concepts

<table>
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<tr>
<th>Crosscutting Concepts</th>
<th>Connections to Classroom Activity</th>
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<tbody>
<tr>
<td>Patterns</td>
<td>Students begin to classify the various foods they taste into different categories. This forms the basis of the understanding that observed patterns of characteristics form the basis of classification.</td>
</tr>
<tr>
<td>Cause and Effect</td>
<td>Students conduct cooking and freezing investigations and determine the cause of observable effects.</td>
</tr>
<tr>
<td>Scale, Proportion, and Quantity</td>
<td>Students begin to classify the various foods they taste into different categories. This forms the basis of the understanding that observed patterns of characteristics form the basis of classification.</td>
</tr>
<tr>
<td>Students compare and contrast their investigation of the decomposition of various fruits and vegetables. Students cook various foods and freeze/unfreeze various liquids we taste throughout the year and use these experiences to explain reversible versus irreversible changes.</td>
<td>Students conduct cooking and freezing investigations and determine the cause of observable effects.</td>
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Observing ladybugs offers opportunities to integrate language arts into a life cycle unit.

By Leslie Bradbury, Rachel Wilson, and Amy Lunceford

Let’s Hear It for Ladybugs!

“I eat bugs. Do you like to eat bugs?”

“You and I are a little bit the same. We can both fly, and we can lay eggs.”

These quotations are from letters written from ladybugs to butterflies at the conclusion of a unit exploring ladybug life cycles. As part of a larger garden project, we implemented a series of integrated lessons with second graders that fueled their excitement and culminated in the release of beneficial insects in our school garden. One of our goals for the unit was to have students connect life cycle concepts, which they had investigated previously with butterflies, to a new organism. Because of students’ comfort level with these insects and their interesting life cycle, ladybugs seemed to be the perfect choice! We used a 5E format to structure our explorations (Bybee et al. 2006) and integrated several language arts activities to support our science inquiries. Using this approach seamlessly met both science content objectives and Common Core State Standards for English Language Arts in a way that captured and sustained students’ attention. To prepare for this unit, we ordered ladybug larvae (see Internet Resources) and assembled materials for a habitat (see A Homemade Habitat, p. 65).
Engage

Our investigation started when we asked the second graders to place a set of photos of the butterfly life cycle in sequential order. These photos, along with others used in the lessons, were downloaded from Wikimedia Commons, a website that provides access to media files such as photos and videos that can be used for free (see Internet Resources). We began in this way to determine students’ prior knowledge. The second graders had begun the school year with a unit on life cycles that included observing butterflies undergoing metamorphosis in the fall, but our ladybug lessons didn’t occur until spring. We thought it was important to see what they remembered, and we hoped that by beginning with a familiar organism, students would be more prepared to predict what might happen with a new animal.

After students organized their butterfly photos, glued them in their science journals, and labeled the pictures, they predicted the stages in the life cycle of a ladybug using drawings and labels. Most students in the class drew an egg, followed by a “baby” ladybug, with an adult ladybug represented in the final stage (see Figure 1). Their “baby” ladybugs looked like miniature adults. Only one student in the class drew a life cycle that included a pupa stage. We were interested to see that the students held these conceptions about the life cycle since they seemed to have such a good understanding of the butterfly life cycle.

![Figure 1. Ladybug life cycle predictions.](image)

![Figure 2. Life cycle observations.](image)

![Figure 3. Ladybug eggs.](image)
Let's Hear It for Ladybugs!

Explore

Our lesson continued on the same day. This portion of the lesson began by sharing a photo of ladybug eggs on the document camera in the classroom. The second graders drew a picture of the eggs and recorded several descriptive words to support their drawings. The students wrote words like, “small, yellow, and round,” to describe the eggs. One observant student stated that the eggs looked “like popcorn kernels.” Students recorded these observations in a chart that they glued into their science journal to organize their data collection (see Figure 2).

We chose to use a photo (Figure 3) during this section because we were not able to find a commercial source for ladybug eggs. Once their descriptions were completed, the students were ready for the “big event.” We brought out a tube containing the ladybug larvae that students would be observing over the next two weeks and asked the students to identify the organisms. The second graders were shocked to learn that the creatures in the tube were the larvae of ladybugs (see Figure 4). Because all of the larvae for the investigation had been delivered in a single tube that included their food, we walked around the room with the tube so that all students could see, and then placed the tube on the document camera and zoomed in to enable students to include as much detail as possible in their drawings and written observations. It is important to note that we only left the tube on the camera for a short time (between 30 seconds and 1 minute). The lights from the document camera could cause the larvae to overheat and die, so after students made their initial observations, we resumed walking around the room with the tube.

Using both drawings and words, the second graders then predicted what the larvae would look like in one week and in two weeks (see Figure 5). For their week 1 predictions, students were divided: Most students believed that the ladybugs would still be in the larva stage but be larger, while others expected that the larvae would have already transformed into an adult. All of the students predicted that they would see an adult ladybug in two weeks.

FIGURE 4.
Ladybug larvae.

FIGURE 5.
Predictions of how the larvae would look in two weeks.
We then placed the larvae in a habitat so that the students could observe them over the upcoming weeks. The habitat was a plastic container that contained the food that had been shipped in the tube with the larvae, along with a water source and a place for the larvae to climb. We used empty toilet paper rolls for a climbing surface. While there are commercial kits available, the larvae successfully completed their transformation to adults in a habitat that we made from common objects (see Figure 6).

Each day over the next few weeks, when the students entered the classroom, they were excited to observe the ladybugs and see whether changes had occurred. Because we had one habitat for our ladybugs, we placed it on a table in the classroom and small groups of students took turns visiting the habitat to discuss what they were seeing and to record information about the ladybugs. The students had sections in their science journals where they included the date, a drawing, and a description of their observations. Additionally, they were asked to record any questions they had about the ladybugs (see Figure 7). Students’ questions showed that they were interested in learning more about many aspects of ladybugs’ lives. For example, the second graders wanted to know whether the ladybugs could swim, how high they could fly, and what bugs they could eat. Drawings over the next week showed that students saw the larvae for about five days, followed by the transition into the pupa stage.

**Explain**

After a week of observations where the students watched the transformation from larva to pupa, we used the nonfiction text *Ladybug* (Schwartz 1999), which contains close-up color photographs, to support the students’ developing understandings of the ladybug life cycle. Each pair of students shared a copy of the book so that they could read along and see the pictures in detail as we read and lead a discussion about the book with the whole class. During the conversation, the second graders compared their own observations with the photographs from the book. We reinforced the idea that so far we had seen the egg, larva, and pupa stages of the life cycle. Additionally, we reviewed what the ladybugs had looked like in each one of those stages and what activities they had engaged in as larvae. We reminded students that if our ladybug larvae were living outside, they would be eating many aphids rather than the food provided by the ladybug suppliers. The students thought that it was very interesting that in nature, the ladybug larvae suck the juices from the bodies of the...
aphids, and they were amazed to learn that one small ladybug larvæ can eat hundreds of aphids.

Because the students had only observed as far as the pupa stage, we used plain white paper and binder clips to cover the pages that revealed what would happen next. Students were excited by the mystery that this generated, and begged us to let them see the covered pages. We explained that they would have to wait to find out the next steps using their own observations. The class discussed what they had seen already and whether any of their earlier questions had been answered. As the class generated new questions, we recorded them on chart paper for future investigation. At this stage, the second graders wanted to know, “How old do ladybugs get?” “Do ladybugs fight each other?” and “Are all ladybugs red?”

**Elaborate**

During the next week, the students continued with their observations of the ladybug pupa in their habitat. They were thrilled when the adult ladybugs began to appear about a week later. Once all of the adults had emerged, we read the final pages of *Ladybugs* (Schwartz 1999) and reiterated the stages of the ladybug life cycle including egg, larva, pupa, and adult. At this point in the lesson, we asked students to revisit the questions that we had generated as a class. We provided pairs of students with copies of the book *Ladybugs* (Gibbons 2012) and had them read it to determine whether they could answer any of their questions. For example, there is one section of the book that shows drawings of ladybugs from around the world including gray, yellow, and orange ladybugs. These opportunities for the second graders to engage with nonfiction texts for a genuine purpose and to answer their own questions using print resources provided a great opening to address *Common Core State Standards* in English Language Arts within the context of a science investigation (see Connecting to the *Common Core State Standards*, p. 66).

The next activity asked the second graders to build their own models of the life cycle of the ladybug using a pliable homemade dough (see Figure 8). We designed this portion of the lesson specifically to address the science practice of Developing and Using Models (see Connecting to the *Next Generation Science Standards*, p. 66). We gave each student an approximately ¾ cup chunk of the modeling material. The students then constructed...
their models of each phase of the life cycle. This part of the unit was especially successful as the second graders were intently focused on including detail in their models. When they began to have questions about specific characteristics of the phases, they referred to their drawings in their science journals and asked for the nonfiction books to double-check their accuracy. This step in the process was particularly exciting as the students were the ones who thought of going back to their journals and books to ensure their models were correct. We took photographs of each student’s model and printed them to add to their journals.

Evaluate

One piece of our evaluation occurred once the ladybugs had reached the pupal stage. We asked the students again to draw the life cycle of the ladybug as they had done in the preassessment, and to predict how long it would take for the next stage to occur. This time there was not a single student who drew the egg, “baby,” adult ladybug life cycle. Every student had drawn an egg followed by a larva. All of the students except for one included a pupal stage after the larva.

On the culminating day of the unit, we combined a writing activity with our ladybug release party. For the writing prompt, we asked the second graders to pretend that they were a ladybug writing a letter to their friend who was a butterfly. Their instructions were to explain to the butterfly how their lives were similar and different. Students were excited to share their science knowledge and their creativity in this assignment, with many students including aspects of a friendly letter along with their content. In this activity, students were able to combine information from their direct observations and their reading about ladybugs to produce a letter that showed what they had learned, addressing one of the Common Core writing standards (NGAC and CCSSO 2010). For example, one student wrote, “I start out as an egg just like you. I do not eat neckter or pollen. We both fly. We both have a shell when we are changing shape. Do you eat aphids? I do. When do you lay eggs?” Another student struggled a bit more with grammar and spelling but included scientifically accurate information. He wrote, “My life cycle is similer to yours. Mine is egg larva pupa adult. Y ours is the same. We both got wings! Do you and me want to be frindes? Your frinde ladybug.” The rubric used to evaluate these letters is available online (see NSTA Connection).

Once the letters were complete, the second graders observed the adult ladybugs one final time. As a class, we discussed the needs of ladybugs and focused on the idea that the adults would not be able to stay in their habitats without the appropriate food or a place to lay their eggs. We also reinforced the idea that both ladybug larvae and adults feed on aphids and other insect pests. We revisited the book Ladybugs (Gibbons 2012), with an emphasis on the final pages that discuss the use of ladybugs to control crop pests. With this information in mind, the students decided that the school

Ladybug Fun Facts

- Ladybugs are also known as lady beetles or ladybird beetles.
- Ladybugs are members of the beetle insect group who have hardened forewings which cover their delicate hind wings.
- During the winter, ladybugs hibernate in places such as rotting logs, under rocks, or in buildings.
- Ladybugs can protect themselves by playing dead or secreting a foul-tasting fluid from their leg joints.

Sources: http://kids.nationalgeographic.com/content/kids/en_US/animals/ladybug and www.lostladybug.org
garden would be the best home for the adults. Our group left the classroom and went out to the garden to release the adults, hoping they would lay their eggs in and around the garden when they were ready.

Conclusion

After reflecting on the experience, we feel that our goals for the unit were achieved. The second graders were extremely enthusiastic throughout the ladybug activities. They had multiple opportunities to use the science practices of Analyzing Data and Obtaining, Evaluating, and Communicating Information as they explored a topic that they found engaging (see Connecting to the Next Generation Science Standards, p. 66). The second graders were able to compare what they had learned about butterflies in the fall with a new insect, and their language arts skills were reinforced as they had the opportunity to read, write, and draw about science in a meaningful context. Let’s hear it for ladybugs as an exciting organism for learning more about animal life cycles!

Leslie Bradbury (upsonlk@appstate.edu) is an associate professor, and Rachel Wilson is an assistant professor, both at Appalachian State University in Boone, North Carolina. Amy Lunceford is a second-grade teacher at Green Valley School in Watauga County in Boone, North Carolina.

Acknowledgments

The authors wish to thank the Reich College of Education at Appalachian State University, which supported this project through a partnership mini-grant that encourages collaborations between public school teachers and university teacher educators.

References


Internet Resources

For teacher background on ladybugs:

National Geographic Kids: Ladybug http://kids.nationalgeographic.com/content/kids/en_US/animals/ladybug

The Lost Ladybug Project www.lostladybug.org

Wikipedia Commons commons.wikimedia.org

Purchasing ladybugs and supplies:

We purchased our ladybug larvae from Insect Lore www.insectlore.com

Plastic models of the ladybug life cycle are available through Carolina Biological Supply Company www.carolina.com

Keywords: Life cycles www.scilinks.org
Enter code: SC150702

NSTA Connection

For the rubric, visit www.nsta.org/sc1507.
Let’s Hear It for Ladybugs!

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

Please note that we conducted this unit in a second-grade classroom, but it is aligned with a third-grade performance expectation. Our state has not yet adopted NGSS, so we did these activities in the grade level that matched our state standard. However, the activities described would be appropriate for a third-grade classroom as well.

3-LS1-1 *From Molecules to Organisms: Structures and Processes*

Please note that we conducted this unit in a second-grade classroom, but it is aligned with a third-grade performance expectation. Our state has not yet adopted NGSS, so we did these activities in the grade level that matched our state standard. However, the activities described would be appropriate for a third-grade classroom as well.

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<tr>
<td>3-LS1-1 Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death.</td>
<td>Students construct a model of the ladybug life cycle that incorporates what they have learned through observing the process and reading non-fiction texts about the life cycle.</td>
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Science and Engineering Practices

<table>
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<th>Developing and Using Models</th>
<th>Students</th>
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<tbody>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>• record observations of ladybugs and analyze the phases of their life cycle,</td>
</tr>
<tr>
<td>Obtaining, Evaluating, and Communicating Information</td>
<td>• obtain relevant information about life cycles from nonfiction texts and compare that to their own observations, and</td>
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<td></td>
<td>• use the information from both sources to construct a physical model of the life cycle of a ladybug.</td>
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Disciplinary Core Idea

<table>
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<tr>
<th>LS1.B Growth and Development in Organisms</th>
<th>Students compare the ladybug life cycle to the butterfly life cycle to identify similarities.</th>
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<tbody>
<tr>
<td>• Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles.</td>
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Crosscutting Concept

| Patterns | Students recognize that there is a predictable pattern that ladybugs go through in their progression from egg to adult by observing the process. |

Connecting to *Common Core State Standards* (NGAC and CCSSO 2010)

**English Language Arts**

**Reading Standards**

CCSS.ELA-Literacy.RI.2.5: Know and use various text features (e.g., captions, bold print, subheadings, glossaries, indexes, electronic menus, icons) to locate key facts or information in a text efficiently

CCSS.ELA-Literacy.RI.2.7: Explain how specific images (e.g., a diagram showing how a machine works) contribute to and clarify a text

**Writing Standards**

CCSS.ELA-Writing.2.8 Recall information from experiences or gather information from provided written sources to answer a question
Making Talk Productive
How to incorporate the reasoning talk move into science conversations

By Sarah Ferris

During the launch of our new unit, my fifth-grade students could not have been more excited about studying space. As we began to explore more content, however, it became increasingly evident that they struggled with building onto each other’s ideas. Too often, students simply nodded their heads “yes” or “no” to agree or disagree with a classmate or did not contribute at all. Others dominated what was meant to be a cooperative group task. How could all students be supported to improve their level of discourse?

Rich discussion not only gives children a chance to dig more deeply into content but also motivates them. The Next Generation Science Standards (NGSS) outline how participation in academic conversations is an essential part of engaging in the science and engineering practices. Unfortunately, the space unit I was using did not explicitly suggest how to get students interacting with the language of science. This article describes how to use the agree/disagree, or “reasoning,” talk move to support students as they formulate arguments during investigations.

Listening and speaking inform our views and allow us to make sense of new information (Vygotsky 1986). Students negotiate meaning and refine thinking based on others’ claims and contributions. Academic conversations involve language structures that set them apart from the kinds of talk students encounter in other settings. Therefore, our increasing awareness of the language demands associated with science content is critical in order to help all students meet the NGSS (NGSS Lead States 2013, Appendix D, Diversity and Equity). By taking a closer look at science curriculum, we can find ways to support structured, academic discourse in our lessons.

What Is the Reasoning Talk Move?

Talk moves (see Figure 1, p. 69) are ways to frame questions and responses when guiding discussions with students and support teacher-student and student-student discourse. Some of these talk moves include revoicing, restating, agree/disagree (reasoning), adding on, and wait time. These five moves serve as a base for teachers to get started with modeling what productive talk sounds like in the classroom (Chapin, O’Connor, and Anderson 2009). Using talk moves can help expand responses and involve a variety of students in the conversation, creating more equitable opportunities for all to participate in constructing knowledge around academic content.

Research suggests that incorporating academically productive talk into lessons can have a positive impact on improving students’ scores on standardized tests while supporting the development of metacognitive thinking, reasoning, and communication skills, as well as enhancing motivation to participate and learn across subject areas over time (Chapin, O’Connor, and Anderson 2009). The example in Table 1, page 68, contrasts the reasoning talk move with the Initiate-Response-Evaluate (IRE) pattern (Cazden 2001), illustrating its potential to extend students’ reasoning while holding them accountable to the discussion and to one another. Below, I discuss how to incorporate the reasoning talk move into instruction.

Step 1: Setting Conversation Expectations

First, deliver a series of lessons to establish expectations using the framework for Accountable Talk (Michaels, O’Connor, and Resnick 2008; see the Accountable Talk sidebar, p. 70), which includes (1) Responsibility to Others (Learning Community), (2) Responsibility to Knowledge, and (3) Responsibility to Thinking (Accepted Standards of Reasoning). This helps with brainstorming a list of norms for group work (see Figure 2, p. 69). Encourage students to contribute spe-
specific examples of what each expectation should look and sound like, and revisit the chart and make revisions, if necessary.

Consider conducting a fishbowl activity to contrast “productive” and “unproductive” group talk, which allows students to visualize and analyze the norms for group work. Every so often, stop the demonstration and pause by “freezing” to debrief what they notice. Resume again by saying “action.” Be sure to reiterate the importance of taking turns, and post directions for the upcoming lesson activity for students to reference (see Figure 3, p. 70).

Next, “start small” and only choose to introduce one new talk move per lesson. Modeling the talk move with the whole group through a conversation about favorite foods, for example, gives students practice first before using it with the lesson content. Have students discuss with partners why they agree or disagree with liking their partner’s favorite food and rehearse how to build onto one another’s ideas while turning, facing each other, and listening carefully. After practicing the norms of conversation, make the transition to the lesson.

### TABLE 1.

**Initiate-Response-Evaluate (IRE) pattern.**

<table>
<thead>
<tr>
<th>Initiate-Response-Evaluate (IRE)</th>
<th>Reasoning, or Agree/Disagree Talk Move</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher: Ok, anyone else?</td>
<td>Teacher: So, why do you agree with David? What makes you agree?</td>
</tr>
<tr>
<td>The teacher evaluates the student’s response without probing to see why the student agrees and moves onto the next question, or initiation, asking more students for responses.</td>
<td>The teacher repeats that the student is agreeing with David and probes further by asking “Why?” and “What makes you agree?” to press the student to think of an example.</td>
</tr>
<tr>
<td>Provides an ending to the interaction between teacher and student without exploring the reasoning behind the student’s response.</td>
<td>Furthers the interaction between the teacher and student. Students are challenged to think of a reason to back up the claims they are either supporting or not supporting. If a student has a difficult time providing a reason, the teacher can give some “time to think,” or wait time. This may help the student come up with reasons by hearing others’ reasoning first. Then the teacher can come back to the student and ask if he or she agrees with any of the reasons given by other classmates. The frame: “I agree/disagree with what ______ said because ______” could help the student respond.</td>
</tr>
</tbody>
</table>

The student’s response to the teacher’s probing of “Why?” above may sound something like this:

Student: Well, remember when we moved around the room and measured the length of the paper from where we were? The paper didn’t change size, but it seemed smaller than it really was so I think things look bigger when they’re closer and smaller when they are farther away.
Step 2: Making Arguments With the Talk Move

The reasoning talk move was chosen for this lesson because students were negotiating decisions about arranging 10 different-size objects printed on picture cards in order from largest to smallest (see Figure 4, p. 71). First, the talk move was modeled within the context of the lesson. Students watched me think aloud, sort, and determine whether we agreed or disagreed with how the cards were sorted by asking the question: Do you agree or disagree and why? This was paired with the sentence frame: I agree/disagree because ________ and the frame: My evidence is ________. Give students time to practice the talk move with partners first and listen in and give feedback before transitioning to small-group work.

After sending students into group work, carefully observe, mingle, and ask probing questions. At times, students may need reminders of the conversation norms and specific feedback can be given (e.g. “I heard you disagree by giving a reason to support your thinking from the chart—that’s using evidence to back up a claim”). Setting out sentence frames on table tents also reinforces framing questions and responses. Examples include:

I agree with ______________ because ______________
I disagree with ______________ because ______________
I see what you are saying…
I’d like to add ______________
It’s your turn.
Thanks for sharing that idea.

After students completed the card sorting activity, an evidence chart of the actual sizes was posted so they could refine, revise, and back up their claims. By re-sorting the 10 objects and making arguments based on evidence with their peers (see Figure 5, p. 72), students were reminded that scientists change their minds after hearing others’ contributions and revise their thinking based on new evidence.

Step 3: Assessing the Reasoning Talk Move

In addition to taking observational notes, have students self-assess with a checklist to reflect on using the reasoning talk move and describe how they feel about participating (see NSTA Connection). My students also thought about their use of two conversational behaviors: turning and looking at the speaker and listening carefully to others. These self-assessments provided valuable feedback about how they felt individually and when working in groups, and this was used to determine future instruction.

Learning logs are another way to assess students’ use of scientific language, understanding of key concepts, and connections to
prior knowledge and personal experiences by having them reflect upon their thinking and jot down any lingering questions. Consider prompts like: I think___, I feel ___, and I wonder ___ and/or using sentence frames that support making arguments (“I agree/disagree with ____ because ____; My evidence is ____”). This also facilitates the transfer of the reasoning talk move into writing.

Increased exposure with the sentence frames allows students to generalize argumentation skills across content domains (e.g., literacy, math, social studies) through oral class discussions and in written discourse on various learning tasks. Teachers can record conversations (e.g., video and audio) to reflect and make future instructional decisions. The class may also analyze their progress with effectively using the talk move by watching or listening to recorded footage. As framing language and reflecting upon its use become a part of the classroom culture, students eventually become less reliant on the frames with continued practice in multiple settings.

Step 4: Reflecting on Student Learning

Some comments circulating around the room as students used the reasoning talk move included:

“I didn’t realize that the stars are bigger than the Moon!”

Another common remark was, “The Sun is only a medium sized star?”

Students repeatedly framed language to agree or disagree respectfully: “I agree, but I’d like to add…,” which was reinforced each time another student sorted the picture cards in the group activity. Disagree-

Accountable Talk

Accountable Talk can scaffold language structures that help all students engage in more productive academic conversations (Michaels, O’Connor, and Resnick 2008). The discourse patterns familiar to some students may differ from the ways discourse is structured daily in classrooms, and Accountable Talk practices have been shown to result in the academic achievement among students of all backgrounds across a variety of grade levels and content areas (Michaels et al. 2008).

For more information on Accountable Talk, visit:

• Institute for Learning
  http://ifi.pitt.edu/index.php/educator_resources/accountable_talk

• Word Generation-Developing Academic Language (Strategic Education Research Partnership)
  http://wg.serpmedia.org/accountable_talk.html

FIGURE 3.
Directions for activity chart.
Listening intently to their discussions, one simple exclamation stood out: “This is fun!” This came after student groups were each given a different key concept from the card-sorting lesson written on a sentence strip (e.g., The Sun looks bigger than other stars because it’s much closer). After rehearsing their thinking, each group presented a key concept using props from around the room. Students were working cooperatively by discussing their reasoning to describe the key concept, agreeing and disagreeing while making decisions, figuring out roles, and negotiating meaning. Seeing them up and moving, applying scientific language and content, with smiles on their faces—this was that “something” that had been missing before.

Closing Thoughts
Continuing to use the reasoning talk move will require ongoing planning, practice, assessment, and reflection. All students will need to practice applying this kind of dialogue in a variety of talk formats including: partner talk, small-group work, whole-group discussions, and small-group presentations (Chapin, O’Connor, and Anderson 2009). Constructing, presenting, and making sense of evidence-based arguments is not only emphasized in the NGSS but also in the Common Core State Standards (NGAC and CCSSO 2010). Teachers can weave this talk move and eventually others into the core of their classroom discussions to expand and challenge students’ reasoning and to work toward meeting these standards. By engaging all students in productive talk, we can help them develop both the social and academic language skills valuable for their continued growth as scientists.

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References

Resources

FIGURE 5.
Evidence chart.

FIGURE 6.
Student sample (pre-assessment and post-assessment).
### Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

**5-ESS1 Earth’s Place in the Universe**

www.nextgenscience.org/5ss-space-systems-stars-solar-system

<table>
<thead>
<tr>
<th>Performance Expectation</th>
<th>Connections to Classroom Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectation listed below. Additional supporting materials/lessons/activities will be required.</td>
<td>Students sort picture cards to support their arguments over which of the various objects in space are larger or smaller based on their relative distances from Earth.</td>
</tr>
</tbody>
</table>

#### 5-ESS1-1 Support an argument that differences in the apparent brightness of the Sun compared to other stars is due to their relative distances from the Earth.

<table>
<thead>
<tr>
<th>Science and Engineering Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engaging in Argument From Evidence</td>
</tr>
<tr>
<td></td>
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<td></td>
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</table>

#### Disciplinary Core Idea

**ESS1.A The Universe and Its Stars**

The Sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.

Students make arguments with peers over their placement of 10 different objects in space by using the sentence frames: I agree/disagree because ______. My evidence is ______.

Students then revise the order of their cards based on the actual sizes of the objects, which is revealed on a chart by the teacher. Students discuss why some objects appear to be larger or smaller based on their size and relative distances from Earth.

#### Crosscutting Concept

**Scale, Proportion, and Quantity**

Students reference the scale model used in class to represent the relative size differences of the Sun, Moon, and Earth. This helps them to make connections from previous learning to support their arguments.
You and Your Students as Green Engineers
Using creativity and everyday materials to design and improve a solar oven

By Tess Hegedus and Heidi Carlone

Educators have been thrown yet another new challenge: teaching engineering to their elementary school students. Challenge accepted! In this article, we highlight one teacher’s journey with her fifth-grade students as they embarked on an engineering adventure together. Ms. Meriwether’s experiences illustrate connections to the Next Generation Science Standards (NGSS) and emphasize opportunities engineering education affords students to think creatively and use 21st-century skills.

Ms. Meriwether was aware of the call to incorporate engineering practices into her science curriculum as part of the NGSS, but how would she get started? Whether driven by bravery or gumption, she headed forward full-steam and participated in a professional development session over the summer for training on the Engineering is Elementary (EiE) curriculum developed by the Museum of Science in Boston. The EiE curriculum consists of 20 units, each highlighting a different field of engineering and science content, aligned with the standards. EiE was developed to provide project-based engineering challenges for students in grades 1–5. Ms. Meriwether chose the solar oven unit based on green engineering as her focus due to the close alignment with her district’s fifth-grade standards and the fourth-grade national standards (see Connecting to the Next Generation Science Standards, p. 81, for solar energy connections). Energy is an important disciplinary core idea that spirals through the standards and grade levels. A “green” engineer develops and applies engineering solutions to environmental problems with a focus on minimizing the depletion of natural resources and reducing environmental impact.

Completing the EiE training was just one piece of the puzzle. Next, she found herself confronted with the reality of presenting the field of engineering and engineering practices to her students as a competent “expert.” To her surprise, the journey was a relatively smooth and enlightening educational adventure. We describe their engineering journey here, showcasing students’ experiences with creative problem solving along with practical strategies for implementing engineering practices into the daily curriculum.

### TABLE 1.
Overview of EiE unit structure

<table>
<thead>
<tr>
<th>Part 1:</th>
<th>Engineering Story (sets the context; series of questions encourages reflection; reinforces literacy skills)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 2:</td>
<td>A broader view of an engineering field (field of focus: green engineering – solar unit; hands-on work done by engineers in this field and the technologies produced)</td>
</tr>
<tr>
<td>Part 3:</td>
<td>Scientific Data Inform Engineering Design (linkages between science, math, and engineering; collect and analyze scientific data to be referred to during the design phase)</td>
</tr>
<tr>
<td>Part 4:</td>
<td>Engineering Design Challenge (design, create, and improve solutions)</td>
</tr>
</tbody>
</table>

Adapted from source: Engineering is Elementary www.eie.org/eie-curriculum/eie-lesson-plan-structure
We chronicle Ms. Meriwether’s journey in four phases, corresponding to the structural arrangement of all EiE units (see Table 1). The four-phase EiE unit framework aligns nicely within the three core ideas of engineering design in the NGSS: (ETS1.A) Defining and Delimiting Engineering Problems; (ETS1.B) Developing Possible Solutions; and (ETS1.C) Optimizing the Design Solution (NGSS Lead States 2013). For teachers who do not have access to this curriculum, resources exist for developing solar ovens using everyday materials, engaging students in problem-based learning, and understanding the plight of people in developing countries by learning about their stories (see Internet Resources).

### Defining and Delimiting Engineering Problems

Parts 1 and 2 of the EiE solar unit closely paralleled the first core idea of Defining and Delimiting Problems in the context of engineering. These parts of the unit provided rich opportunities for meaningful connections to the social studies, science, literacy, and mathematics curriculum. What did this look like in practice?

#### Part 1: The Story

Due to predictable time limitations during the instructional day, Ms. Meriwether utilized her English language arts (ELA) time (an hour in the morning) to read the EiE story: *Lerato Cooks Up a Plan: A Green Engineering Story* to students. Ms. Meriwether began with a summary of the story, providing visuals from the text on a projector. She initiated class discussions about the story’s setting, context, genre, and characters. In the story, Lerato, a young girl in Botswana, is in charge of the family dinner, including the time-consuming and resource-intensive task of collecting firewood for cooking their food. Tsoane, her sister’s friend who is studying green engineering at a university, gives Lerato a solar oven that does not require wood for fuel, but it does not work well at first. Lerato improves the design with knowledge of thermal insulators and conductors, though her precise solution is left intentionally vague. The problem of the story, how to build a well-insulated solar oven with reduced impact on the environment, set the context for the design challenge students would tackle later in the unit.
The book prompted questions about science and engineering issues (e.g., how the use of fires for heating can negatively impact the environment). This is where potential environmental impacts—aspects of green engineering—were discussed in the story and within the classroom. One student commented that green engineers are people who “go out and use natural resources to solve problems in the world.” Another student added that the word environment or tikologo includes “nature and our surroundings.” Students discussed environmental impacts such as air pollution, soil erosion, and deforestation as issues that green engineers must consider to help preserve the environment. At this point, Ms. Meriwether initiated an activity to examine the use of paper (a naturally-derived resource commonly used by students in the classroom).

**Part 2: Introducing Green Engineering**

In this session, youth learned about one strategy (assessments of natural resources) that green engineers use to define and delimit problems. The session began with practice in divergent thinking strategies. Students worked in groups of 3–4 to brainstorm as many uses for paper as they could in two minutes time. The students became quite competitive, in a hurry to fill their lists with many ideas in the allotted time. Each group brainstormed 14–30 ideas, including: toilet paper, name tags, school notebooks, paper plates, tickets, tests, lunch cards, tissues, signs, and so on. Students estimated the quantity of classroom paper used weekly by performing calculations, making mathematical connections. The brainstorming session extended into another activity, where students sequenced cards that represented the steps in the life cycle of paper (see Figure 1, p. 75). This emphasized the importance of reducing, reusing, and recycling. The class discussed life cycle assessments as part of green engineers’ jobs. Life cycle assessments are engineers’ way of understanding the life cycle of human-made products, to include the examination of resources required for development,
environmental impact, and any possible improvements that can be made. Students would use life cycle assessments later in the unit.

Part 1 of the unit set the stage by introducing the central engineering problem (how to create a well-insulated solar oven with the least environmental impact) within the context of an engaging multicultural story. Part 2 allowed students to think like environmental engineers by conducting a life cycle assessment of paper to evaluate environmental impacts of using a natural resource. By understanding paper use in the classroom and the importance of reusing and recycling materials used on a daily basis, students were better able to grasp the need to protect natural resources (e.g., firewood) as they worked to develop alternative human-made technologies for cooking food. Defining and delimiting the problem (ETS1.A) in these ways provided a foundation for designing solutions for insulating a solar oven using materials with reduced environmental impact (parts 3 and 4).

**Designing Solutions to Engineering Problems**

**Part 3: Testing Properties of Materials**

The unit’s next step involved testing different materials for their insulating properties. Students remained curious about the solar oven construction and offered their questions and ideas about materials they might use. One boy asked if the plastic wrap that goes on his sandwich was a good insulator. He pondered aloud how his lunch box was constructed by analyzing its insulating components. A girl commented that they would need to do something to the inside of the ovens to insulate them against heat loss. The students gasped with excitement when Ms. Meriwether presented the prototype oven (a modified shoe box) and let them know they would be making modifications on this design. Hands rushed up as students shared their ideas for how to design the boxes to yield the best insulation.

Students tested potential thermal insulators (craft foam, felt, newspaper, foil, plastic grocery bags, construction paper), changing the configuration of those materials (flat or shredded), developing ranking criteria (1–10 scale: “1” for the best insulator and “10” for the worst), and evaluating materials based on their environmental impact (natural or human made, quantity needed, reusability, and recyclability). Cups lined with flat or shredded materials were placed in a large ice bath and secured in place to accommodate the 12 total testing stations (see Figure 2, p. 75). The teacher secured 12 cups in advance to the bottom of the large plastic tub using a silicone adhesive. Students nested their testing cups inside the secured ones for stability. Ideally, there would be 12 student groups, 6 groups testing the flat and 6 groups testing the shredded insulators. Prior to testing, students made predictions about how the materials might perform in the test by considering their physical properties. Students monitored the temperature change of their assigned cup every 30 seconds for three minutes. Ms. Meri-
Meriwether reviewed lab safety procedures prior to testing and instructed students in the reading and safe use of the school’s glass thermometers. Safety goggles are recommended when using glassware in the lab. The class shared results and conducted an environmental impact analysis (see Figure 3, p. 76) to determine the optimal materials, based on their insulating properties, for use in part 4, the design phase of the project. In part 3, students collected and analyzed scientific data about the insulating properties of materials and in the process, made important linkages between science, mathematics, and engineering.

Optimizing the Design Solution

Part 4: Engineering Design

Students used their knowledge of thermal properties of materials and environmental impact (from part 3) along with the iterative Engineering Design Process (ask, imagine, plan, create, and improve), to design their solar ovens in pairs (see Figure 4, p. 77).

Ms. Meriwether directed students to imagine or brainstorm some ideas for their design. They considered the advantages and disadvantages of using certain materials, the configuration of those materials, and how many “units” they would need. One unit of flat material was equal to one 8.5 × 11 sheet (e.g., felt or foam) or one cup of shredded material (e.g., newspaper or loose cotton balls). In doing so, they thought about the insulating properties of the materials in addition to their environmental impacts. The planning stage required labeled schematic diagrams for the distribution and placement of materials. Students used the Impact Scoring Sheet (see Figure 5) to determine trade-offs of using certain materials. For example, using natural materials resulted in a lower (desired) overall score versus the higher-scoring processed materials. Once constructed (create) in groups of two, students took ovens outside into a sunny location on the school grounds and began recording the change in temperature (with reflective lids open to direct the Sun’s rays) at five-minute intervals for 30 minutes total (see Figure 6). Students had proper sun protection to avoid overexposure when outdoors. At the end of this period, they moved ovens to the shade and recorded the temperature change every minute for 10 minutes. Ms. Meriwether managed a control box (with no insulation) for comparison.

During testing, students scrambled around their boxes, shouting out temperature changes: “Mine is at 100 degrees!” “Ours is at 124!” Another female student was already thinking about how to improve her oven,
exclaiming, “I know exactly what to do!” The session was not without its challenges. One boy stepped on and broke his thermometer in the excitement. Digital thermometers are recommended to avoid breakage and safety concerns, if school funds are available. Another group read the Celsius markings instead of the prescribed Fahrenheit readings, confusing their findings. All in all, however, the high level of student engagement and ideal afternoon weather conditions made the session a roaring success.

The next day, Ms. Meriwether conducted a class debrief of the temperature changes, and students calculated their total scores. After evaluating the oven designs that lost the least heat, students improved their designs and considered how to lower their environmental impact scores, retesting outside in a subsequent session.

What Did We Learn?
The Now You’re Cooking: Designing Solar Ovens EiE unit aligns neatly within the three NGSS core ideas of engineering (ETS1.A, ETS1.B, and ETS1.C) and the NGSS Energy performance expectation 4-PS3-4. Additionally, the unit challenged students to think creatively and to experience productive moments of failure.

Thinking Creatively
Through the Engineering Design Process, students experienced what it means to think creatively. First, students created multiple designs that presented more than one solution to a problem. Collaboration was an important element in this process. Sawyer (2012) noted that groups tend to be more creative than individuals and that cognitive diversity and group composition are critical elements in organizing creative groups. Second, students’ divergent, flexible thinking emerged through brainstorming sessions about uses of paper and ways to insulate their solar ovens. Third, students developed novel ways to use ordinary materials in parts 3 and 4 of the unit. The design and improve phases prompted students’ creative solutions, with opportunities to face a problem from different vantage points (see Figure 7, p. 80).

Productive Moments of Failure
Encouraging multiple solutions to a problem, moving away from the traditional model of one right answer, can present challenges to students who are not used to experiencing failure. Throughout the unit, students repeatedly engaged with the problem and persisted in finding a viable solution. Ms. Meriwether emphasized this point with students during the improve phase of the design process. She let students know that her original design during a professional development session with EiE was not successful until she did some improvements. In this way, she shared her previous “failure” with students. Ms. Meriwether asked students if they would “feel like a failure” if they did not experience the desired results? One boy responded, “You don’t want to feel like a failure.” Ms. Meriwether reiterated to the boy and the class that “you are not a failure” if the design is not initially successful. She guided their attention back to the work of green engineers who learn from their previous designs flaws and use that information to improve on future designs. The improve phase of the Engineering Design Process provided students with new ways of approaching and solving problems, moving away from traditional right-or-wrong thinking.
Conclusion

Although implementing engineering practices may sound daunting, Ms. Meriwether showed that it is not an impossible proposition. In this case, literacy, social studies, mathematics, science, and engineering were integrated by making use of a multicultural story to engage students and set the stage for an engineering-based problem. Students could perform themselves scientifically by conducting controlled experiments in order to explore the properties of materials. They collected, analyzed, and reported their findings in a collaborative, scientifically oriented manner to gain knowledge about how to solve an authentic problem. Finally, the Engineering Design Process (ask, imagine, plan, create, and improve) allowed students to think creatively, experience productive failure, and optimize their design solutions in a real-world fashion. You can, too—take the challenge!

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Internet Resources

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http://journeytoforever.org/sc_link.html

Library of Congress: Selected resources on solar ovens and solar cooking
www.loc.gov/rr/scitech/SciRefGuides/solarovens.html

Solar Cookers International: Solar cooking in the classroom
www.solarcookers.org/involved/teachers-and-students

TeachEngineering: Creating a solar oven
## Connecting to the Next Generation Science Standards (NGSS Lead States 2013)

### 4-PS3 Energy and 3-5-ETS1 Engineering Design

[www.nextgenscience.org/4ps3-energy](http://www.nextgenscience.org/4ps3-energy) • [www.nextgenscience.org/3-5ets1-engineering-design](http://www.nextgenscience.org/3-5ets1-engineering-design)

### Performance Expectation

*The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectation listed below. Additional supporting materials/lessons/activities will be required.*

### Connections to Classroom Activity

**4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.**

Students test materials for their insulating properties and use that knowledge to build a solar oven with the goal of reduced impact on the environment.

### Science and Engineering Practices

**Asking Questions and Defining Problems**

**Planning and Carrying Out Investigations**

**Analyzing Data**

**Constructing Explanations and Designing Solutions**

Students

- conduct tests on materials to determine their insulating properties.
- analyze data to determine the best insulating materials to use in their solar ovens.
- construct, test, and improve solar oven designs.

### Disciplinary Core Ideas

**PS3.B Conservation of Energy and Energy Transfer**

- Energy is present whenever there are moving objects, sound, light, or heat.

**ETS1.A Defining and Delimiting the Problem**

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

Students use solar energy to heat food in an insulated solar oven.

Students

- generate lists in small groups or whole class discussion regarding the criteria and constraints of the problem presented
- participate in class discussion using questions about the story to encourage reflection
- are exposed to the specific field of engineering indicated in the problem by exploring the hands-on work done by engineers in this field and the technologies produced

### Crosscutting Concepts

**Energy and Matter**

**Influence of Science, Engineering and Technology on Society and the Natural World**

Students test and use various materials to enhance the transfer of energy.

Students improve the solar ovens.
Q: How Do You Date Fossils?

By Bill Robertson

There are a number of ways. The bar scene can be sketchy. You could also try match.com or eHarmony, but my understanding is that you should stay away from Tinder because it’s just a hookup app. Of course, you have to ask yourself why you would want to date a fossil (someone my age, for instance) in the first place. Ho, ho, ho, wasn’t that fun? A much better question for this column would be How do you determine the age of a fossil?, but if I’d used that, then I couldn’t begin with lame jokes.

So, we want to know how scientists determine how old fossils and rocks are. Just as with the other kind of dating, there are lots of ways. To begin, get several sheets of paper and place them in a stack on the table. Next pick up the top sheet, then the next sheet, and then a third sheet, and answer a question: Which of those three sheets do you think was placed in the stack first? Which one second? Which one last? Pretty simple, right? Unless some gremlin in your house was trying to fool you for some silly reason having to do with stacking sheets of paper, it’s a reasonable assumption that the sheet you picked up last was placed in the stack first, and the sheet you picked up first was placed in the stack last. Let’s take that simple lesson and apply it to figuring out how old different layers of the Earth are.

By layers I mean the layers of rocks and minerals and dirt that are evident in every place where people or natural forces have exposed them. Think the Grand Canyon. Think places where people have blasted through mountains large and small in order to build roads. If you don’t have personal experience with either of those, just find a photo of the Grand Canyon (or any canyon for that matter) and notice the layers of rock that are apparent on the sides. In the case of the Grand Canyon, these layers have been exposed gradually as the Colorado River has worn a path down to its current position. In looking at those layers, we’re looking back in time. It makes sense, based on our stack of papers analogy, that the layers near the top were deposited most recently and the layers near the bottom were deposited long ago.

These deposited layers give us one way to determine the relative age of fossils contained in the layers. Fossils in higher-up layers are not as old as fossils in lower-down layers. Of course, there are difficulties with this method. The Earth’s crust moves and creates areas of upheaval and depression. Fault lines (places where different parts of the crust have sheared across each other) can move the horizontal layers in vertical directions. Also, erosion can completely remove layers in one area while leaving the same layers in other areas undisturbed. Other processes, which I won’t go into here, mess things up further. So, it’s not like we have nice, clear layers of deposited material all around the Earth. And finally,
this only gives us the relative age of fossils. It doesn’t tell us exact ages, because there’s no way of knowing exactly how long it took for different layers to form. See Figure 1.

Before continuing, I have to explain the process of radioactive decay. You probably know that all atoms contain protons and neutrons in the nucleus, and electrons outside the nucleus (hydrogen is an exception, in that it doesn’t have a neutron in its most common form). Certain atoms are unstable, in the sense that they spontaneously transform into a different atom. This can happen in lots of ways. A neutron can transform into a proton (Really!), with the release of an electron and another particle known as an antineutrino. Or, a proton can transform into a neutron, with the release of a positron (a positively charged electron—yes, such particles exist) and a regular neutrino. Other forms of decay include electron capture (in which the nucleus absorbs an electron) and gamma emission (just the release of high energy photons). Figure 2 shows the process of radioactive decay of carbon-14. The 14 tells you the total number of protons and neutrons. Carbon-14 decays into nitrogen-14, which has the same total number of protons and neutrons as carbon-14 (hence the number 14 after each one), but the nitrogen-14 has 7 protons while carbon-14 has 6 protons. You might recall from earlier knowledge of chemistry that the number of protons determines what element you have. Everything with 6 protons is carbon and everything with 7 protons is nitrogen, regardless of how many neutrons are in the atom.

Back to figuring out the age of fossils. One way of getting a more exact age of fossils is to use what’s known as carbon dating. Carbon exists in several forms, and one of the forms is the aforementioned carbon-14. Carbon-14 is present in very small amounts in the atmosphere. Radioactive elements have a half-life. The half-life indicates the time it takes for half of a sample of the element to decay. The half-life of carbon-14 is 5,730 years, meaning that if you start with 100 grams of carbon-14, in a mere 5,730 years you will have about 50 grams of the element. In another 5,730 years, you’ll have half of that amount, or about 25 grams. Now, if only fossils contained radioactive carbon. Oh wait. They do. During its life, any organism on the planet, as a result of exchanging carbon with the atmosphere (this happens in respiration in both plants and animals), has a certain percentage of carbon-14 in all of its tissues. When the plant or animal dies, it stops exchanging carbon with its surroundings and the carbon-14 in it continues to decay into nitrogen-14 (It’s a transformation of one atom into another, so the mass of the fossil doesn’t change). Assuming that all organisms have the same percentage of carbon-14 in them when they die (a big assumption, it turns out), we can just look at the amount of carbon-14 in a fossil compared to the amount of carbon-12 (this is by far the most abundant form of carbon, which is non-radioactive), compare that to the relative amounts of the two carbons assumed to be in the organism when it died, and determine, using the half-life of carbon-14, how long ago the organism died. As with
all dating methods, there are issues (insert your own lame joke here). First, we have assumed that the relative amounts of carbon-14 and carbon-12 in the atmosphere have been constant throughout the Earth’s history. Turns out that’s not true, which is one of the problems with carbon dating. Second, this method only works if the fossil is composed of organic (carbon containing) material. Many fossils have none of the original organic material from the organism remaining. The fossil could contain minerals that have displaced the original organism, or the fossil might just be an imprint of the organism. Third, we can only use carbon dating to go back about 70,000 years. That’s because the half-life of carbon-14 is relatively short in geologic years, and after about 70,000 years, there isn’t enough carbon-14 left to provide a significant measurement.

By now you’re probably getting the idea that no one dating method is foolproof for determining the age of a fossil. Going by layers in the Earth’s surface only gives a relative age of fossils, and involves solving the puzzle of what happened to layers in different parts of the Earth. Carbon dating relies on a number of assumptions, and it can only take us back 70,000 years. Fortunately, there are other dating methods. Another radioactive dating method is using the decay of potassium-40 (radioactive) into argon-40 (non-radioactive). Potassium is found in lots of rocks and minerals. When certain kinds of rocks and minerals are formed, they’re molten, as in liquid. In that state, any argon-40 that’s produced from the decay of potassium-40 can escape into the air. After formation, however, the argon-40 is trapped in the material. So, you can look at a rock or mineral and determine the relative amounts of potassium-40 and argon-40, and figure out how long that decay has been taking place. Potassium-40 has a half-life of about 1.25 billion years, so clearly this dating method can take us much farther back in time than can carbon dating. But this decay doesn’t rely on organic material, we can also use it to date regular rocks as well as fossils that have had their organic matter replaced with minerals. Then, by assuming that rocks found next to fossils in the same layer of the Earth’s crust are about the same age, we can figure out the age of fossils that might not contain potassium. And as you might expect, that’s not the only assumption involved. We assume that no argon-40 manages to find its way into already-formed rocks and that no argon-40 manages to escape already-formed rocks. Both assumptions fall apart in certain cases, but there are ways of correcting for that.

Other decay processes help us date rocks. Uranium-238 decays into lead, with a half-life of about 4.5 billion years, which happens to be about as old as the Earth itself, so clearly we can then date fossils and rocks as old as the Earth. Uranium and other radioactive elements also leave “fission tracks,” which are records of the damage caused when radioactive particles make their way through a material. The number of fission tracks is an indication of how long the radioactive substance in the rock has been decaying. There are many other ways of dating rocks and fossils, including investigation of luminescence (producing light) in rocks caused by atmospheric radiation throughout the rock’s time on Earth, and even investigation of the spin of electrons (a property that all electrons have) in the atoms of substances. Too many methods to explain adequately, so I’ll just end with one of the more interesting dating methods. To understand this, it will help if you can find a compass. As you learned as a kid, one needle of a compass points north and the other points south. The compass needle is actually a tiny magnet, and what it’s doing is aligning itself with the Earth’s magnetic field. Magnets do that; they align themselves with the magnetic field produced by another magnet. So yes, the Earth is a magnet. Now, find a metal filing cabinet that’s been sitting in the same place for a while. No, “the cloud” doesn’t count as a filing cabinet, though it is likely making it
more and more difficult to find regular filing cabinets. Anyway, bring your compass needle near different corners of the metal filing cabinet—top right, top left, lower right, and lower left. If the cabinet hasn’t been moved in a while, you’ll find that the north end of the compass needle is attracted to certain corners of the cabinet and the south end of the compass needle is attracted to other corners of the cabinet. What this means is that the filing cabinet itself is magnetized. Over time, the atoms of the metal, which are themselves magnets, have aligned themselves with the Earth’s magnetic field.

Okay, so what? Well, it turns out that lots of rocks and minerals contain elements whose magnetic moments (fancy name for the magnetic nature of atoms inside the elements) align with the Earth’s magnetic field just as a filing cabinet will. That alone doesn’t help us date any rocks (lame jokes keep popping into my head, but I’ll spare you), but the fact that the direction of the Earth’s magnetic field has changed many times in its history does. How do we know that the Earth’s magnetic field has changed? By looking at places in the deep oceans where the sea floor is spreading. These are places where we’re getting “new crust” for the Earth, consistent with the whole notion of plate tectonics, which will have to be the subject of a different column. If you examine the rocks and minerals at the places where the sea floor is spreading, you’ll see a pattern of magnetic alignment that looks like the drawing in Figure 3.

When the rocks form from molten magma at the spreading point, their magnetic moments are free to align with the Earth’s magnetic field. After the rocks solidify, the magnetic moments are locked into place. So, Figure 3 shows us that the Earth’s magnetic field must have switched directions as the sea floor spread. By measuring how fast the sea floor is moving away from the spreading point (pretty slow—around 5 cm per year. For a cool simulation, see the link in the Internet Resource section), we can figure out how long each period of alignment with the Earth’s magnetic field lasted. Then, we can compare this information with the alignment of the magnetic moments in rocks and minerals contained in various layers of the Earth that aren’t on the sea floor. That’s great, except that our information from sea floor spreading doesn’t come close to taking us back to the age of the Earth. Therefore, we have to use the alignment of magnetic moments as a confirmation method to bolster more direct ways of determining the ages of rocks and minerals.
To summarize, we have lots of ways to determine the age of a fossil. We use the layers of the Earth, comparisons with rocks and minerals in those layers, radioactive dating, other physical processes such as luminescence and electron spin resonance, and the alignment of magnetic moments with the Earth’s magnetic field. No one method solves the problem, and there are lots of assumptions built into each method. The more methods we have, though, the more each can support others. If you’re bothered by all this imprecision and use of assumptions, just remember that we’re dealing with the real world and with an older Earth that we can’t observe directly. We might know a whole bunch about radioactive decay and electron spin and magnetic fields individually, but when you bring them together to analyze natural processes, it can be difficult. I often use the following example, which I might have absorbed from some famous scientist at some point in my younger life. Imagine a paper bag blown down a street by the wind. We can know all there is to know about forces and how they affect paper bags, and all there is to know about what causes wind and how wind blows down a particular street, but there is no way in the world to predict exactly where that paper bag will end up. The real world is just too chaotic for us to know that. That doesn’t mean we can’t get close in our prediction, though!

Bill Robertson (wrobert9@ix.netcom.com) is the author of the NSTA Press book series, Stop Faking It! Finally Understanding Science So You Can Teach It.
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**My School Yard Garden**
By Steve Rich.
$12.95. 32 pp.
NSTA Press.
Arlington, VA.

This book caught my eye with its stunning photographs illustrating the relationships between plants in a school garden and the animal life those plants support. There are many “how-to” books on the market that provide information about the logistics of gardening, but this book is unique in its approach to teaching students in grades K–3 about the interdependent relationships in ecosystems.

A theme throughout this book is the importance of being mindful of setting up sustainable habitats in areas of development. A school yard garden provides an opportunity to involve students in creating and nurturing a space to grow things for our enjoyment and nourishment, as well as to learn about the benefits of host plants and planned-landscaping concepts to neighboring creatures.

The book encourages children to make observations in the garden area and then work with a personal nature journal, including sketches to go with what they write. There is a glossary for young gardeners to use, as well as helpful lists of references and websites. Steve Rich includes an important note with information for parents and teachers. His ideas are invaluable when thinking about beginning a school yard garden. All of this could also help someone who wants to garden with a youngster outside of school, at home or in the community.

I am very glad to recommend this book for teachers to read aloud to the
whole class and for students to enjoy individually or in pairs to develop different concepts of life science. The text and corresponding photos in this book provide interesting facts about ecology, recycling and decomposition, requirements of living things, food chains and webs, life cycles, and nutrition. I especially appreciate the author’s inclusion of social studies concepts. Students will learn about sharing their bountiful harvest with those less fortunate, American colonists’ first gardens and creative use of plants for food as well as medicine, and the “three sisters”—beans, corn, and squash—in the tradition of the Native American people.

Debby Chessin

The Computer Wore Heels

The title itself of The Computer Wore Heels is very intriguing and when the iPad app is opened, it continues in an interesting vein and draws the reader into the story of several young women with mathematical talents. These women are being called on to serve their country during the years of World War II. The story itself is designed to be of interest to young women who may not think that mathematics is a cool area or one worth pursuing.

At the beginning of World War II, many young men were joining to fight in the European and Pacific theaters. This meant that many jobs that had previously been held by males needed to either be filled by females or left unfilled. Some of the jobs were vital to the country’s war effort. The posters of Rosie the Riveter were showing up everywhere, enticing women to consider doing things they had not conceived of doing. Working with mathematical formulas to help plot bombing runs and help bomb-site development was one of the areas that needed smart people; young women provided that help for America’s armed forces, particularly the three chronicled heavily in this iPad app.

Upon first opening the app, there is a video of a train traveling down the tracks. Other spots in the book have audio tracks and pop-out photo enlargements. The level of interactivity is enticing to readers and certainly is a change from the more staid printed books. Older elementary students through high school would enjoy the app. While the educational connections in the app itself are limited and presentation strategies would depend on the creative teacher, there is a teacher guide available on a companion website (https://sites.temple.edu/thecomputerworeheels/files/2014/03/CWH-study-guide.pdf). The one missing link, which would be good to have, is additional connection to the various scientific, mathematical, and technical learning outcomes. It would not be impossible for a teacher to make the connections, but a direct link might help in using the app.

The story of the young ladies working on mathematics formulas first on paper and later on the first of the electronic computing machines (ENIAC) was interesting to read. Their story will be unknown to many readers. The connection of females to math, science, and technology will be helpful in bringing gender equity to the forefront. Having this app available on classroom iPads for student use would help encourage females to pursue fields where they are still underrepresented. The need to have an iPad might be a hindrance in some class settings, but some students might like to get their own copy. While it is not necessary to have everyone reading the story at the same time, it might help to have a number of students read and discuss it for others. The app does not have an option to allow for reading in a portrait orientation; it is available only in landscape orientation.

The menu can be retrieved on most pages, but it is located far to the left side of the pages and requires some experimenting to tap far enough to the left side of a page to find the menu. All in all, this is a good app and is recommended because of both the technical quality of the presentation and also because of the subject matter. The app is inexpensive enough to buy several for general classroom use or for multiple machines in the media center. Students should enjoy it and also learn a great deal—always a good combination.

Steve Canipe

Question It!

Question It! explains the process of observing and asking questions. One of four books in a series, the book explains to students what scientific questions are and how to create questions that are both testable and safe.

This book is not likely one to be picked up off the media-center shelf to be read by a student. Thus this book is more for the teacher to use when explaining the scientific process to a class. The book has a strong connection to the Next Generation Science Standards’s
science and engineering practices and would be great to use when planning and conducting an investigation. This book would also be great for teaching text features in reading.

Question It! has a great layout with lots of photographs for kids to look at. Also, all of the photographs have labels, so students won’t question what they are looking at. The book has a kid-friendly glossary, where the definitions are scientifically accurate and written in simple terms. The words in the glossary are color-coded by noun, verb, and adjective, which is another great connection to reading and writing.

I like that this book also has a “question with care” page that helps students create questions that can be answered without harming living things. This allows children to see the importance of conducting meaningful and respectful investigations. I think it is great that a children’s book brings this topic up. It opens the door for teachers to have that difficult discussion with their students. The book gives students three questions to think about when creating a testable question: Is this a question? Is it safe to try? Will it harm any living thing? These are three basic questions that students can ask themselves after creating their testable question. There are several websites presented in this book, as well. They are all in working order, kid-friendly, and safe. Lastly, the book is very appealing and colorful, which will help keep your students engaged.

I think that this is a great book for students in first and second grade who might not be familiar with creating testable questions. The information presented in this book would not be age appropriate for students in grades 4 and 5. As a second-grade teacher, I would use this book before we conduct our first classroom investigation. It would also be good to revisit this book throughout the school year to remind students what a good scientific question looks like. I really enjoyed reading the book and think that it would be a great resource to help students further understand how to share their science investigations.

Stacy Van Dyken

John Muir Wrestles a Waterfall
By Julie Danneberg.
$16.95.
Charlesbridge Publishing.

Imagine you are pinned on a narrow ledge behind a waterfall with a 2,425-foot drop—higher than two Empire State Buildings stacked on top of each other. It is cold, dark, and dangerous. The thundering of the water matches the thundering of your heart in your chest. You are cold, shivering, and shaking. This is the experience of John Muir described in this book for children ages 4–8. Muir was at Yosemite Falls.

John Muir stayed there from 1868 until 1871 while running a small lumber mill. He watched the sun paint rainbows on the falls during the day and the moonbows at night. Muir could see the falls and the stars through the roof of his cabin where he kept his journals, sketches, and books. During this experience, Muir climbed up beside the waterfall and found a granite ledge that cut across the rock wall. He inched along the ledge until he could touch the falls. A strong wind actually lifted the water away from the rocks and he went behind the falls before the wind died down and the water fell back in place.

Muir believed that nature should be experienced firsthand and did so. He slept in a rock in the middle of a river, climbed a 100-foot fir tree during a storm, and stood outside in the middle of an earthquake. While these activities were not particularly safe, he believed nature should not be feared but rather enjoyed and appreciated. He studied nature by borrowing books and taught himself science and geology. John wrote articles for newspapers and magazines and realized he could make a living by writing while still devoting himself to his desire to preserve nature. Theodore Roosevelt spent quite a bit of time with Muir. Roosevelt later created the national parks and monuments system that we enjoy today in part because of the influence of John Muir. Muir also founded the Sierra Club, which still promotes saving and enjoying nature.

Below the text on several pages is
additional information about Muir, along with two pages of further information at the back of the book. Ten books about John Muir as well as six websites to learn more about him are provided. Citations to Muir’s letters are also given. Parts of the text use alliteration to enhance the suspense of the story. This book would pique the curiosity of any reader. It would be a great jumping-off point for many facets of learning—biographies, preserving nature, conservation, and writing journals. I highly recommend this book.

Jacqueline Pfeiffer

Inventions That Could Have Changed the World...But Didn’t!

An engine-powered pogo stick, a fully operational trumpet that also shoots a flame, a bird feeder that attaches to your head for close-up observation. How about an alarm clock that also triggers your bed to dump you onto the floor? These, and many other inventions, are the subject of Inventions That Could Have Changed the World...But Didn’t! Be grateful.

The book is divided into chapters of failed inventions in the areas of travel, games, caring for children and pets, items for the home, and fully interactive food. The first chapter addresses the concept of invention as a solution to a problem. It encourages kids to identify a problem and have a go at an invention. The book also reviews the patenting process and questions that inventors must consider before their invention can be marketed and considered a success. The illustrations are based on the actual patents for each invention.

Colorful, cartoonlike illustrations show what just might happen if you were to actually use the invention, such as your house burning down while heating bacon in a toaster. An inventor index and references for even more failed inventions accompany the text. The book is a great starting point for discussions about innovation, engineering, and other STEM-related topics. Seeing what went wrong can be as helpful as seeing what went right. It becomes clear that for every Edison lightbulb, there are many more patents for items such as motorcycle handles for corn on the cob (complete with engine sounds!), umbrellas for dogs, and parachute coats. Be the last on your block to get one. Meanwhile, I’m still holding out for my rocket jet pack.

Rebecca Bell

Kitchen Science Lab for Kids

Need some new ideas that will engage your K–8 students at home, in after-school activities, or even at parties? Kitchen Science Lab for Kids is a great book for both the school and family library. This book is filled with simple experiments using inexpensive, everyday ingredients. There is one fun science activity for every week of the year.

Each experiment is presented on a one-page layout complete with child-centered illustrations and text that accommodates even young readers. The pages are well organized, labeled, and follow the same format, including a materials list, safety tips, protocol, science concepts behind the fun, and enrichment ideas. These suggestions are a great way to extend thinking for budding scientists while they have fun and stay safe. The book is available in a flexibound format as well as a Kindle version. Why not enjoy the creative 52 discoveries together? What a year of science that would be!

Karen Nesbit

Teaching Science for Understanding in Elementary and Middle Schools

Would you like to be able to teach science for deeper student understanding? As one looks at a resource book for the first time, the first and last chapters should provide the key to unlocking the contents. This is true in the case of Teaching Science for Understanding in Elementary and Middle Schools, which contains 10 helpful chapters and a conclusion.

The focus of the book is on what teachers should do in the classroom and how they should interact with their students. These interactions include asking questions that stimulate student discussions that will foster a student’s own understandings. It also addresses ways to develop student skills that enable students to understand the world around them. The first chapter provides three short scenarios that are referred
to in other chapters in the book. This chapter also includes a list of six areas that teachers should address as they manage student learning. The author says that students should be engaged, manipulate real objects, explain their prior knowledge, talk to each other, gather evidence, interpret results, and experience activities that are well planned. It becomes obvious early in the book that the students should take control of their own learning and develop understandings and knowledge through their own experiences.

Chapter two addresses how to teach science. Included is timely information about neuroscience and learning. There is a chapter about developing scientific skills necessary for inquiry such as questioning, making observations, analyzing data, interpreting information, and communicating. The chapter about argumentation and reflective thinking is right on target for helping students develop critical-thinking skills. There are chapters on formative assessment and more. The concluding chapter lists eight underlying principles that should determine the how, the what, and the why of science teaching. Each chapter ends with a short summary section called “Action Points” summarizing key ideas in that chapter.

I found this volume very practical and useful for teaching science for understanding. I feel that the author’s approach—focusing on what the child does, thinks, says, and understands—is the key to the child’s comprehension of difficult science concepts necessary for mastery of the scientific world. Guiding a child to fully develop is essential for this to occur. There is definitely too much information to absorb in one single read. Rather, this volume should be used as a resource to improve an educator’s overall skills. I can see this volume being used in a study-group situation where a group of teachers reads a chapter, discusses the information, puts it into practice in their classrooms, and then reports back to the group for further discussion about what they discovered. As a seasoned educator of over 30 years, I recommend this volume.

Adah Stock

What’s for Lunch?


Our global village is reflected in classrooms across the country. Diversity is recognized, customs are respected, and holidays are celebrated. Food is an integral part of every culture and lunch is the students’ shared experience. In What’s for Lunch? How Schoolchildren Eat Around the World, Andrea Curtis takes the reader on a worldwide journey to explore the variety of meals shared during the school day.

The continental tour begins in Tokyo, Japan, where lunch is more than a meal. Etiquette, respect, and cleanliness are integral components. The meal itself typically consists of fish, miso soup, rice, a vegetable, and milk. Nantes, France, encourages a slow-paced meal, savoring the concoctions cooked by trained chefs. There is an intense appreciation of food, and lunchroom meals are served on ceramic plates accompanied by silverware. Bread and cheese are often part of the meal, with low-fat meats and vegetables also served.

In both Canada and the United States, food is often prepackaged from vending-machine items to curb sugar intake. From England, to Russia, and on to China, additional meals are photographed by Yvonne Duivenvoorden to complement the text. Each location is carefully identified on a globe and illustrations of traditional attire introduce each featured country. In closing, the author includes a message to parents, educators, and students about the power of food. There is a fast-food, disposable mindset that is seeping into the international food system. Ramifications of lunch choices should be considered for the health of the individual as well as the environment.

Judy Kraus

Coming Up

Our next issue will explore Engineering and Design. Here’s a preview:

- Community-Based Engineering
- Engineering Adaptations
- The Engineering Design Process 5E
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Program/Ticket Information

P-1: I would like to GO GREEN and PAPERLESS and receive an electronic version (ePDF) of the final conference program. This PDF will be sent via e-mail approximately two weeks before the conference. (See reverse for details.)

Ticket information for short courses, field trips, and networking events will be available online in late July.

Payment

Registration Fee $_________
Spouse/Guest Fee $_________
NSTA Membership Fee (form attached) $_________
Total Due: $_________

I am paying by:
☐ Check #_________ (payable to “National Science Teachers Association” in U.S. funds)
☐ Credit Card:
☐ AMEX ☐ Discover ☐ MasterCard ☐ VISA
Card # ___________________________
Expiration Date ___________________________

Signature ___________________________

☐ School Purchase Order (copy attached):
PO # ___________

Mail your completed form with payment to National Science Teachers Association, Conference Dept., PO Box 90214, Washington, DC 20090-0214, FAX: 703-243-3924, or register online at www.nsta.org/conferences.
Registration Instructions
This form is for the use of conference participants only. Individuals registering to conduct business should contact Jason Sheldrake, Assistant Executive Director, NSTA Sales, at 703-312-9273 to register as a Non-exhibiting Industry Representative.

Each registrant (except nonteaching spouse) must submit a separate registration form. Do not send duplicate registrations—if you fax your form, do not also mail the form. For complete information on registration, including rates, deadlines, spouse and guest fees, and more, go to www.nsta.org/confreg.

Registration fees cover all nonticketed conference activities and entry to the Exhibit Hall. Fees do not cover ticketed events, meals, lodging, or transportation other than NSTA-contracted shuttle service.

By registering to attend a National Science Teachers Association (NSTA) conference, you grant permission to NSTA to take and use your photo in NSTA marketing and promotional pieces for an indefinite period of time. Marketing and promotional pieces include, but are not limited to, printed brochures, reports, postcards, flyers, and materials, as well as online uses such as postings on the NSTA website, online newsletters, and e-mail blasts. NSTA shall own all rights, including copyrights in and to the photos. You also grant permission to NSTA to use, encode, digitize, transmit, and display the video/audio of your session, presentation, or workshop given at the NSTA conference, singularly or in conjunction with other recordings, as well as to use your name, photograph, biographic information, and ancillary material in connection with such video/audio for commercial, promotional, advertising, and other business purposes. NSTA and its employees are released from any liability arising out of the use of your name, video, photographs, and/or organization name and location.

Earlybird/Advance Deadlines
Registrations submitted online, postmarked, or faxed by the earlybird deadline or the advance deadline have substantially lower fees than those for on-site registration.

You must register by the advance deadline to receive your badge, tickets, and confirmation in advance of the conference. If you submitted your registration before the advance deadline and if by three weeks before the conference you have not received your confirmation packet, call NSTA conference registration at 703-243-7100 or 800-328-8998 or e-mail reg@nsta.org.

If your registration is received online or postmarked/faxed after the advance deadline, you will be charged the full on-site rate and your confirmation may not be mailed to you before the conference. Pick up your confirmation, badges, and tickets on-site at the Conference Services Counter in the NSTA Registration Area.

Ticketed Events
Tickets for short courses, field trips, networking events, and other special events will be available for purchase in late July. You may register for the conference using this Advance Registration Form and add tickets to your registration later by submitting a new registration form (check the box on the new form that indicates that you have already registered for the conference). In late July, details and descriptions of ticketed events will be available on our website (www.nsta.org/conferences). Tickets are nonrefundable.

Refund/Cancellation Policy
Refund requests must be in writing and must be postmarked 10 days before the conference. Badge materials must be returned with refund request. Registration cancellations are subject to a $20 processing fee. Ticketed events are nonrefundable.

Questions?
Contact NSTA conference registration at 703-243-7100 or 800-328-8998, or via e-mail at reg@nsta.org. For general information on the fall conferences or to register online, visit our website at www.nsta.org/conferences.

Submitting Your Registration
Payment for registration and membership (if attaching membership application) must be included with your registration form. Forms received without payment will be returned unprocessed. Payment may be made by check, credit card, or purchase order from your school or school district (attach forms for all registrants). Mail your completed form with check or credit card payment to:

National Science Teachers Association
Conference Department
PO Box 90214
Washington, DC 20090-0214
FAX: 703-243-3924

Become an NSTA member and Save $95* on your conference registration!
Complete the membership application available on the following pages and send it (along with membership fees and your fall conference registration form/payment) to:

National Science Teachers Association
Conference Dept., PO Box 90214
Washington, DC 20090-0214

Or fax to: 703-243-3924. Registration and applications are also available online at www.nsta.org.

NSTA gives you the tools and resources to excel in your career and saves you time and money by equipping you with already vetted resources, research, products and materials, and access to the information you need to apply to your classroom.

Just a few of the many benefits include:
- Access to members-only listservs
- A subscription to one of NSTA’s award-winning journals
- 20% discount on NSTA Press® publications
- Fresh, NEW lesson plans to enliven your classroom

Learn more at www.nsta.org/membership

(*when you register for 2–3 days in advance)
Get Great Benefits All Year Long—Join NSTA Today and Save!

Gain year-round access to the latest news and information affecting science education.

1. **Membership Options** Each membership option listed below includes one journal.
   - Individual Membership—$79/yr.
   - Student—$39/yr. For students enrolled in an accredited college or university with an interest in science education only. Include proof of current registration with your payment. Instructor must sign here:
   - New Teacher—$39/yr. Teachers who are in their first five years of teaching. Send a copy of your teaching certificate or a letter from your administrator.
   - International Regular Membership—$94/yr. (one journal only)
   - International Electronic Membership—$39/yr. (no hard copy journal and no U.S. addresses)
   - Retired—$39/yr. Science educators who are fully retired and have been an NSTA member for at least five years.

   **Available for the 2015 Reno Area Conference**
   - NSTA/NSSTA—$75/yr. includes membership in both Nevada State Science Teachers Association and NSTA (NEV15).

   **Available for the 2015 Philadelphia Area Conference**
   - NSTA/PSTA—$105/yr. includes membership in both Pennsylvania Science Teachers Association and NSTA (PSTA15).

   **Available for the 2015 Kansas City Area Conference**
   - NSTA/STOM—$85/yr. includes membership in both Science Teachers of Missouri and NSTA (STOM15).
   - NSTA/KATS—$90/yr. includes membership in both Kansas Association of Teachers of Science and NSTA (KATS15).

2. **Contact Information** (please print)
   - Name ________________________________
   - Title ________________________________
   - Institution __________________________
   - Home __________________ Work ________
   - Address ______________________________
   - City __________________ State _________ Zip __________
   - Country _____________________________
   - Work Phone __________________________
   - Home Phone __________________________
   - Fax _________________________________
   - E-mail ______________________________
   - Twitter handle _______________________
   - No _______ Yes ____ ID# ________
   - I am interested in receiving information from NSTA about a leadership position.
   - Please remove my name and postal address from the mailing list NSTA makes available to other organizations.

3. **MEMBERSHIP JOURNALS** Select the journal you would like to receive as part of your membership:
   - Science & Children—9 times a year; grades K–6
   - Science Scope—9 times a year; grades 6–9
   - The Science Teacher—9 times a year; grades 9–12
   - Journal of College Science Teaching—6 times a year; college

   To subscribe to more than one journal, call NSTA Member Services at 800-722-NSTA (6782) or 703-243-7100.

4. **GRADES** (check all that apply)
   - Pre-K    4th Grade    9th Grade
   - Kindergarten 5th Grade 10th Grade
   - 1st Grade 6th Grade 11th Grade
   - 2nd Grade 7th Grade 12th Grade
   - 3rd Grade 8th Grade College

5. **DISCIPLINES** (check all that apply)
   - Earth and Space Science    Physical Science
   - Biology/Life Science    General Science
   - Chemistry    Computer Science
   - Physics    Tech Education
   - Environmental Science Other__________

6. **Payment Method**
   - School Purchase Order enclosed. PO# ____________
   - Check enclosed, payable to the “National Science Teachers Association” (U.S. Dollars)
   - Please charge my credit card: MasterCard VISA Discover AMEX

Card # ______________ Expiration Date ______________

Name on card ___________________________ Signature ______________

Four Easy Ways to Join NSTA
1. Visit www.nsta.org
2. Fax your completed form to 703-243-3924
3. Mail your completed form with payment to NSTA, PO Box 90214, Washington, DC 20090-0214.
4. Call NSTA Member Services at 800-722-NSTA (6782) or 703-243-7100.
INSTRUCTIONS
Housing reservations can be made in one of the following ways beginning May 18.

- Internet * Preferred
  For payments via credit card
  www.nsta.org/renohousing
  Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner’s Club, Discover, Visa, and MasterCard.

- Telephone
  877-352-6710 (toll free)
  801-505-4611 (international)
  Call between 7:00 AM and 6:00 PM Mountain Time, Monday—Friday. Be prepared to provide all the information on this form.

- Fax (Use one form per room request)
  801-355-0250

- Mail (Use one form per room request)
  DO NOT MAIL TO NSTA
  *Mail CHECKS ONLY to:
  Orchid Event Solutions—NSTA/Reno
  175 South West Temple, Suite 30
  Salt Lake City, UT 84101

DEADLINE
Reservations must be made by September 24, 2015.

CONFIRMATIONS
Orchid Event Solutions will send you a confirmation of your reservation. Please review all information for accuracy. E-mail confirmation will be sent if an e-mail address is provided (preferred), or confirmation can be faxed or mailed. If you do not receive a confirmation or if you have questions, call Orchid Event Solutions. You will NOT receive a confirmation from the hotel.

TAX RATE and SPECIAL REQUESTS
All rates are per room and are subject to a 13% sales and lodging tax (subject to change). Special requests cannot be guaranteed; however, hotels will do their best to honor all requests. Hotels will assign specific room types upon check-in, based on availability.

ROOM DEPOSIT REQUIRED TO SECURE RESERVATION
All reservations must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing Forms received without a valid guarantee or deposit will not be processed. Check deposits must be mailed with a completed housing form payable to “Orchid Event Solutions.”

CANCELLATION POLICY
Cancellations made after September 24 and prior to 24 hours before arrival date will be subject to a $25 cancellation fee. One night’s room charge and tax will be forfeited entirely if cancellation occurs within 24 hours of arrival.

<table>
<thead>
<tr>
<th>HOTEL</th>
<th>SINGLE</th>
<th>DOUBLE</th>
<th>TRIPLE</th>
<th>QUAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Atlantis Casino Resort Spa (Headquarters Hotel)</td>
<td>$149</td>
<td>$149</td>
<td>$149</td>
<td>$149</td>
</tr>
<tr>
<td></td>
<td>summit luxury $125</td>
<td>$125</td>
<td>$125</td>
<td>$125</td>
</tr>
</tbody>
</table>

A Reno Hotel Map is available at www.nsta.org/renohousing.

Please select hotel choices in order of preference and enter their numbers below.

1st __________________________ 2nd __________________________

Room Type Requested:  □ One Bed  □ Two Beds

If requested hotels are unavailable, a reservation will be made at the next available hotel.

Please select criteria:  □ Comparable room rate  □ Proximity to conference site

Submit only one room request per form. Should additional forms be needed, please make copies.

List all room occupants (include yourself):
______________________________  __________________________________
______________________________  __________________________________
______________________________  __________________________________
______________________________  __________________________________

□ Check here if you require special services  □ Nonsmoking request
Special requests: __________________________________

DEPOSIT INFORMATION
All reservation requests must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing forms received without a valid guarantee or deposit will not be processed. Faxed requests must include a valid credit card. Check deposits must be mailed with a completed housing form.

Type:  □ American Express  □ Diner’s Club  □ Discover  □ MasterCard  □ Visa

Card number: __________________________ Exp. Date: ________________

Name on credit card: __________________________________

Cardholder’s signature*: __________________________________

*I hereby authorize Orchid Event Solutions or any one of the hotels to process a charge to my credit card for each room deposit in accordance with the policies provided herein no sooner than September 24, 2015.

□ One night’s check deposit enclosed and made payable to Orchid Event Solutions. Mail housing forms to Orchid Event Solutions—NSTA/Reno, 175 South West Temple, Suite 30, Salt Lake City, UT 84101. Check deposits must be received by September 24 to be accepted.
**NSTA Philadelphia Area Conference**

**Official Housing Request Form**
November 12–14, 2015, Philadelphia, Pennsylvania

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**CONTACT INFORMATION**

First: __________________________ Mi: _______ Last: __________________________

E-mail: __________________________
School/Company: __________________________

Address: __________________________
City: __________________________ State: ________ Postal Code: __________________________

Phone: __________________________ Fax: __________________________

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**HOTEL SELECTION**

**Arrival Date:** __________________________ **Departure Date:** __________________________

<table>
<thead>
<tr>
<th>HOTEL</th>
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<th>TRIPLE</th>
<th>QUAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Philadelphia Marriott Downtown (Headquarters Hotel)</td>
<td>$228</td>
<td>$228</td>
<td>$248</td>
<td>$268</td>
</tr>
<tr>
<td>2. Hampton Inn Philadelphia Center City–Convention Center</td>
<td>$199</td>
<td>$199</td>
<td>$209</td>
<td>$219</td>
</tr>
<tr>
<td>3. Home2 Suites by Hilton Philadelphia–Convention Center</td>
<td>$214</td>
<td>$214</td>
<td>$224</td>
<td>$234</td>
</tr>
</tbody>
</table>

Please select hotel choices in order of preference and enter their numbers below.

1st __________________________ 2nd __________________________

Room Type Requested:  □ One Bed  □ Two Beds

If requested hotels are unavailable, a reservation will be made at the next available hotel. Please select criteria:  □ Comparable room rate  □ Proximity to conference site

Submit only one room request per form. Should additional forms be needed, please make copies.

List all room occupants (include yourself):

______________________________________________________

□ Check here if you require special services  □ Nonsmoking request

Special requests: ________________________________________________________________

---

**DEPOSIT INFORMATION**

All reservation requests must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing forms received without a valid guarantee or deposit will not be processed. Faxed requests must include a valid credit card. Check deposits must be mailed with a completed housing form.

Type:  □ American Express  □ Diner’s Club  □ Discover  □ MasterCard  □ Visa

Card number: __________________________ Exp. Date: __________________________

Name on credit card __________________________

Cardholder’s signature __________________________

*I hereby authorize Orchid Event Solutions or any one of the hotels to process a charge to my credit card for each room deposit in accordance with the policies provided herein no sooner than October 12, 2015.

□ One night’s check deposit enclosed and made payable to Orchid Event Solutions. Mail housing forms to Orchid Event Solutions–NSTA/Philadelphia, 175 South West Temple, Suite 30, Salt Lake City, UT 84101. Check deposits must be received by October 12 to be accepted.

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**INSTRUCTIONS**

Housing reservations can be made in one of the following ways beginning **May 18**.

- **Internet * Preferred**
  - For payments via credit card
    - www.nsta.org/phillyhousing
  - Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner’s Club, Discover, Visa, and MasterCard.

- **Telephone**
  - 877-352-6710 (toll free)
  - 801-505-4611 (international)
  - Call between 7:00 AM and 6:00 PM Mountain Time, Monday–Friday. Be prepared to provide all the information on this form.

- **Fax** (Use one form per room request)
  - 801-355-0250

- **Mail** (Use one form per room request)
  - DO NOT MAIL TO NSTA
  - *Mail CHECKS ONLY to:*
    - Orchid Event Solutions–NSTA/Philadelphia
    - 175 South West Temple, Suite 30, Salt Lake City, UT 84101.

**DEADLINE**

Reservations must be made by **October 12, 2015**.

**CONFIRMATIONS**

Orchid Event Solutions will send you a confirmation of your reservation. Please review all information for accuracy. E-mail confirmation will be sent if an e-mail address is provided (preferred), or confirmation can be faxed or mailed. If you do not receive a confirmation or if you have questions, call Orchid Event Solutions. You will NOT receive a confirmation from the hotel.

**TAX RATE and SPECIAL REQUESTS**

All rates are per room and are subject to a 15.5% sales and lodging tax (subject to change). Special requests can be honored; however, hotels will do their best to honor all requests. Hotels will assign specific room types upon check-in, based on availability.

**ROOM DEPOSIT REQUIRED TO SECURE RESERVATION**

All reservations must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing forms received without a valid guarantee or deposit will not be processed. Check deposits must be mailed with a completed housing form payable to “Orchid Event Solutions.”

**CANCELLATION POLICY**

Cancellations made after **October 12** and prior to 24 hours before arrival date will be subject to a $25 cancellation fee. One night’s room charge and tax will be forfeited if cancellation occurs within 24 hours of arrival.

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**REVOLUTIONARY SCIENCE**

**PHILADELPHIA, PA**

**NOVEMBER 12-14, 2015**

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**Deadline:**

**October 12, 2015**
INSTRUCTIONS
Housing reservations can be made in one of the following ways beginning May 18.

- Internet * Preferred
  - For payments via credit card
    www.nsta.org/kchousing
  - Please have your credit card and arrival/departure information ready. Accepted credit cards include American Express, Diner’s Club, Discover, Visa, and MasterCard.

- Telephone
  - 877-352-6710 (toll free)
  - 801-505-4611 (international)
  - Call between 7:00 AM and 6:00 PM Mountain Time, Monday–Friday. Be prepared to provide all the information on this form.

- Fax (Use one form per room request)
  - 801-355-0250

- Mail (Use one form per room request)
  - DO NOT MAIL TO NSTA
  - *Mail CHECKS ONLY to:
    Orchid Event Solutions–NSTA/Kansas City
    175 South West Temple, Suite 30
    Salt Lake City, UT 84101

DEADLINE
Reservations must be made by November 4, 2015.

CONFIRMATIONS
Orchid Event Solutions will send you a confirmation of your reservation. Please review all information for accuracy. E-mail confirmation will be sent if an e-mail address is provided (preferred), or confirmation can be faxed or mailed. If you do not receive a confirmation or if you have questions, call Orchid Event Solutions. You will NOT receive a confirmation from the hotel.

TAX RATE and SPECIAL REQUESTS
All rates are per room and are subject to a 16.85% tax rate plus $1.75 city development tax (subject to change). Special requests cannot be guaranteed; however, hotels will do their best to honor all requests. Hotels will assign specific room types upon check-in, based on availability.

ROOM DEPOSIT REQUIRED TO SECURE RESERVATION
All reservations must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing Forms received without a valid guarantee or deposit will not be processed. Check deposits must be mailed with a completed housing form payable to “Orchid Event Solutions.”

CANCELLATION POLICY
Cancellations made after November 4 and prior to 48 hours before arrival date will be subject to a $25 cancellation fee. One night’s room charge and tax will be forfeited entirely if cancellation occurs within 48 hours of arrival.

**Please select hotel choices in order of preference and enter their numbers below.**

1st __________________________ 2nd __________________________

Room Type Requested:
- [ ] One Bed
- [ ] Two Beds

HOTEL SELECTION

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</tr>
</thead>
<tbody>
<tr>
<td>1. Kansas City Marriott Downtown (Headquarters Hotel)</td>
<td>$159</td>
<td>$159</td>
<td>$159</td>
<td>$159</td>
</tr>
<tr>
<td>2. Holiday Inn Kansas City Downtown–Aladdin</td>
<td>$115</td>
<td>$115</td>
<td>$115</td>
<td>$115</td>
</tr>
</tbody>
</table>

A Kansas City Hotel Map is available at www.nsta.org/kchousing.

Please select criteria:
- [ ] Comparable room rate
- [ ] Proximity to conference site

Submit only one room request per form. Should additional forms be needed, please make copies.

**List all room occupants (include yourself):**

- [ ] Check here if you require special services
- [ ] Nonsmoking request

Special requests:

DEPOSIT INFORMATION

All reservation requests must be accompanied by a valid credit card guarantee or check for one night’s deposit. Housing forms received without a valid guarantee or deposit will not be processed. Faxed requests must include a valid credit card. Check deposits must be mailed with a completed housing form.

Type:
- [ ] American Express
- [ ] Diner’s Club
- [ ] Discover
- [ ] MasterCard
- [ ] Visa

Card number: __________________________ Exp. Date: __________________________

Name on credit card: __________________________

Cardholder’s signature: __________________________

*I hereby authorize Orchid Event Solutions or any one of the hotels to process a charge to my credit card for each room deposit in accordance with the policies provided herein no sooner than November 4, 2015.

- [ ] One night’s check deposit enclosed and made payable to Orchid Event Solutions. Mail housing forms to Orchid Event Solutions–NSTA/Kansas City, 175 South West Temple, Suite 30, Salt Lake City, UT 84101.

Check deposits must be received by November 4 to be accepted.
MAKE THE MOST OF NSTA COPYRIGHTED MATERIALS

NSTA allows classroom teachers to use its materials in the following ways:

• All educators may reproduce up to five copies of an NSTA article or book chapter for personal use only. This does not include display or promotional use.

• All educators may reproduce and e-mail an NSTA article or book chapter in their possession to as many as five individuals for personal use only. This does not include promotional use.

• Elementary, middle, and high school teachers, as well as educators in a university setting, may reproduce a single NSTA article or book chapter for one-time classroom or noncommercial, professional-development use only. This does not apply to coursepacks.

NSTA has established specific conditions under which it will grant permission to reuse content from the NSTA website, NSTA journals, and NSTA Press books. To request permission for approved uses and pay the associated fees, please contact the Copyright Clearance Center (CCC) at www.copyright.com. CCC is a not-for-profit organization that provides licenses for the use of NSTA content. For more information about NSTA permissions policies, please go to www.nsta.org/permissions.
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#5. Unlimited access to journal articles

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#8. Countless NGSS@NSTA resources

#9. Online learning

#10. Professional development opportunities year-round

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