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Misconceptions abound concerning the relationship between the Earth, Sun, and Moon. In this issue, we examine ways to teach these difficult concepts accurately.

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The first NSTA STEM Forum & Expo will bring together nationally renowned STEM experts and practitioners and hands-on educators interested in learning about successful approaches and implementation of Science, Technology, Engineering, and Mathematics education into our schools and districts. STEM best practices, content, and integration processes are critical aspects for creating well-trained elementary and middle school educators who will need to radically increase student literacy in these STEM subjects. Join this very important discussion on STEM.

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Teacher Growth, Coupled With Early Introduction

It’s tiny out there...it’s inconsequential. It’s ironic that we had come to study the Moon and it was really discovering the Earth.

— Bill Anders

Misconceptions abound concerning the relationship between the Earth, Sun, and Moon. When I hear my colleagues talk about teaching these concepts, I’m reminded of the research done surrounding the understanding of the reasons for seasons (a study that included questioning recent Harvard graduates on the topic). To this day, I’m amazed to hear educated people explain this using their incorrect understanding. Recently a video appeared on YouTube that highlighted another misunderstanding: distances in space. This was a less formal study of a general population, but we are not teaching these phenomena effectively.

I have my own ideas about why this is occurring. First, of all the concepts that are difficult to teach, the relationship between the Earth, Sun, and Moon includes many preconceived ideas ingrained in students before they have had formal education inform them. Some of this is due to myths and folklore, whereas others are due to incorrectly connecting what they see and experience in their every day lives to what they see in the sky. Taking Science to School (NRC 2007) states that “some of the most dramatic changes [in understanding] may occur during the elementary years with respect to cosmology” (p. 74). Second, it may be because teachers don’t have a full understanding of the relationship between the Earth, Sun, and Moon. Many elementary teachers have acquired their K–16 education without an astronomy or Earth science course. I’m included in that number and pursued that type of course only after completing several years of teaching and having learned of my misconceptions. Third, perhaps we are waiting too long and do not logically introduce these concepts to our students. They are teachable—and learnable—at many levels at various degrees of sophistication. Early introduction of the core ideas and developing a logical progression will help students develop accurate understanding.

As we consider the changes needed to align with the new Framework (NRC 2011), and ultimately the forthcoming new standards, we should begin by assessing the current learning progressions surrounding the development of core concepts such as distances between the bodies in our galaxy; the movement of the Earth, Moon, and Sun; and the cause of seasons. We should also evaluate our personal growth for understanding these concepts and reach out for learning and teaching tools.

References
Learning and Teaching Scientific Inquiry
Research and Applications
Grades K–8
Science teacher educators, curriculum specialists, professional development facilitators, and K–8 teachers will increase their understanding and confidence when teaching inquiry after reading this definitive volume. The authors assert that scientific inquiry is best taught using models in science rather than focusing on the routine activities of scientists. Additional emphasis is placed on cognitive science research, providing insight on how students learn and how instructors should teach. Also included are extensive examples, practice problems, activities, and lesson ideas that apply research findings to practical scenarios for the classroom.
Members: $23.96 | Non-members: $29.95

Models-Based Science Teaching
Grades K–12
K–12 teachers who are interested in expanding their thinking about the nature of science should consider Models-Based Science Teaching. Author Steven Gilbert asserts that all learning involves the construction of mental models, defined as “simplified representations of what we think we know.” He begins with a philosophical context for modeling and includes discussion questions and recommended resources and readings with each chapter. In Gilbert’s words, “The best way to engage students in the creativity of science is to engage them in inquiry, beginning with the creation of a problem and ending with a completed expressed model.”
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Science the “Write” Way
Grades K–8
Writing skills are high on the list of real-world requirements for students and teachers. Every scientific discipline needs professionals who can ably describe their proposed studies for funding consideration, record observations and results, provide written experimental protocols for their peers, and share their findings with the community. This useful compendium outlines the process and the methods for teaching science writing lessons and also offers practical assessments. Lab reports, science journals, field guides, interactive science notebooks, blogs, and even creative nonfiction and environmental poetry are covered.
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Core Ideas of Engineering and Technology
Understanding A Framework for K–12 Science Education

By Cary Sneider


This article addresses Chapter 8 of the Framework, which presents core ideas in technology and engineering at the same level as core ideas in the traditional science fields, such as Newton’s laws of motion and the theory of biological evolution. Although prior standards documents included references to engineering and technology, they tended to be separate from the “core content” of science, so they were often overlooked.

Giving equal status to engineering and technology raises a number of important issues for curriculum developers and teachers, a few of which I will discuss in this article:

- How does the Framework define science, engineering, and technology?
- What are the core ideas in Chapter 8?
- Why is there increased emphasis on engineering and technology?
- Is it redundant to have engineering practices and core ideas?
- Do we need to have special courses to teach these core ideas?
- Will teachers need special training?
- What will it look like in the classroom?

How does the Framework define science, engineering, and technology?

The meaning of these terms is summarized in the first chapter of the Framework as follows:

In the K–12 context, “science” is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) Earth, space, and environmental sciences. . . . 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. Likewise, we broadly use the term “technology” to include all types of human-made systems and processes—not in the limited sense often used in schools that equates technology with modern computational and communications devices. Technologies result when engineers apply their understanding of the natural world and of human behavior to design ways to satisfy human needs and wants. (NRC 2011, pp. 1–3, 4)

Notice that engineering is not defined as applied science. Although the practices of engineering have much in common with the practices of science, engineering is a distinct field and has certain core ideas that are different from those of science. Given the need to limit the number of standards so that the task for teachers and students is manageable, just two core ideas are proposed in Chapter 8. The first concerns ideas about engineering design that were not addressed in Chapter 3, and the second concerns the links among engineering, technology, science, and society.

What are the core ideas in Chapter 8?

As with core ideas in the major science disciplines, the two core ideas related to engineering and technology are first stated broadly, followed by grade band endpoints to specify what additional aspects of the core idea students are expected to learn at each succeeding level. Following are brief excerpts from the rich descriptions in the Framework:

Core Idea 1: Engineering Design

From a teaching and learning point of view, it is the iterative cycle of design that offers the greatest potential
for applying science knowledge in the classroom and engaging in engineering practices. The components of this core idea include understanding how engineering problems are defined and delimited, how models can be used to develop and refine possible solutions to a design problem, and what methods can be employed to optimize a design. (NRC 2011, p. 8–1)

- By the end of second grade, students are expected to understand that engineering problems may have more than one solution and that some solutions are better than others.
- By the end of fifth grade, students are expected to be able to specify problems in terms of criteria for success and constraints, or limits, to understand that when solving a problem it is important to generate several different design solutions by taking relevant science knowledge into account and to improve designs through testing and modification. In some cases it is advisable to push tests to the point of failure to identify weak points.
- By the end of middle school, students should be able to recognize when it makes sense to break complex problems into manageable parts; to systematically evaluate different designs, combining the best features of each; to conduct a series of tests to refine and optimize a design solution; and to conduct simulations to test if–then scenarios.
- By the time they graduate from high school, students should be able to do all of the above and, in addition, formulate a problem with quantitative specifications; apply knowledge of both mathematics and science to develop and evaluate possible solutions; test designs using mathematical, computational, and physical models; and have opportunities to analyze the way technologies evolve through a research and development (R&D) cycle.

Core Idea 2 (Links Among Engineering, Technology, Science, and Society) has two components that are more distinct than the three components of engineering design, so they are listed separately.

Core Idea 2A: Interdependence of Science, Engineering, and Technology
The fields of science and engineering are mutually supportive. New technologies expand the reach of science, allowing the study of realms previously inaccessible to investigation; scientists depend on the work of engineers to produce the instruments and computational tools they need to conduct research. Engineers in turn depend on the work of scientists to understand how different technologies work so they can be improved; scientific discoveries are exploited to create new technologies in the first place. Scientists and engineers often work together in teams, especially in new fields, such as nanotechnology or synthetic biology that blur the lines between science and engineering. (NRC 2011, p. 8–2)

- By the end of second grade, students should know that engineers design a great many different types of tools that scientists use to make observations and measurements. Engineers also make observations and measurements to refine solutions to problems.
- By the end of fifth grade, students learn more about the role played by engineers in designing a wide variety of instruments used by scientists (e.g., balances, thermometers, graduated cylinders, telescopes, and microscopes). They also learn that scientific discoveries have led to the development of new and improved technologies.
- By the end of eighth grade, students learn that engineering advances have led to the establishment of new fields of science and entire industries. They also learn that the need to produce new and improved technologies (such as sources of energy that do not rely on fossil fuels and vaccines to prevent disease) have led to advances in science.
- By the time they graduate from high school, students should be aware of how scientists and engineers who have expertise in a number of different fields work together to solve problems to meet society’s needs.

Core Idea 2B: Influence of Engineering, Technology, and Science on Society and the Natural World
The applications of science knowledge and practices to engineering, as well as to such areas as medicine and agriculture, have contributed to the technologies and the systems that support them that serve people today. . . . In turn, society influences science and engineering. Societal decisions, which may be shaped by a variety of economic, political, and cultural factors, establish goals and priorities for technologies’ improvement or replacement. Such decisions also set limits—in controlling the extraction of raw materials, for example, or in setting allowable emissions of pollution from mining, farming, and industry. (NRC 2011, p. 8–1)

- By the end of second grade, students recognize that their lives depend on various technologies and that life would be very different if those technologies were to disappear. They also understand that all products are made from natural materials and that creating and using technologies have impacts on the environment.
- By the end of fifth grade, students realize that as people’s needs and wants change so do their demands for new and improved technologies that drive the work
By the time they graduate from high school, students are aware of the major technological systems that support modern civilization; how engineers continually modify these systems to increase benefits while decreasing risks; and how adoption of new technologies depends on such factors as market forces, societal demands, and government support or regulation. By the end of 12th grade, students should be able to analyze costs and benefits so as to inform decisions about the development and use of new technologies.

Why is there increased emphasis on engineering and technology?

The commitment to engineering and technology in the Framework is extensive, as references to these terms are found throughout the document. A rationale for this increased emphasis is stated in different ways at a number of places in the Framework. One reason is inspirational, as described in the following paragraph:

We anticipate that the insights gained and interests provoked from studying and engaging in the practices of science and engineering during their K–12 schooling should help students see how science and engineering are instrumental in addressing major challenges that confront society today, such as generating sufficient energy, preventing and treating diseases, maintaining supplies of clean water and food, and solving the problems of global environmental change. In addition, although not all students will choose to pursue careers in science, engineering, or technology, we hope that a science education based on the Framework will motivate and inspire a greater number of people—and a better representation of the broad diversity of the American population—to follow these paths than is the case today. (NRC 2011, p. 1–2)

A second reason is practical. The value of developing useful knowledge and skills is summed up in the following: First, the committee thinks it is important for students to explore the practical use of science, given that a singular focus on the core ideas of the disciplines would tend to shortchange the importance of applications. Second, at least at the K–8 level, these topics typically do not appear elsewhere in the curriculum and thus are neglected if not included in science instruction. Finally, engineering and technology provide a context in which students can test their own developing scientific knowledge and apply it to practical problems; doing so enhances their understanding of science—and, for many, their interest in science—as they recognize the interplay among science, engineering, and technology. We are convinced that engagement in the practices of engineering design is as much a part of learning science as engagement in the practices of science. (NRC 2011, p. 1–4)

Is it redundant to have engineering practices and core ideas?

This is an excellent question, especially because there is no corresponding chapter about core ideas of scientific inquiry. However, a close reading of the document will reveal that although there is some overlap between Chapter 3 and Chapter 8, very little of the content is redundant. Chapter 3 treats engineering design as a set of practices that are similar to scientific inquiry. So students may develop these abilities in the context of asking and answering questions about the world as well as systematically solving problems. Chapter 8 expands on engineering design in ways not mentioned in Chapter 3, addressing such issues as systematically evaluating potential solutions, testing to failure, and the process of optimization.

Also, a major focus of Chapter 8 concerns the interrelationships among science, engineering, technology, society, and the environment, which are essential for all students and are not addressed anywhere else in the document. An important message of this set of core ideas is that it is important for everyone not only to know how to design technological solutions to problems, but also to think broadly about the potential impacts of new and improved technologies and to recognize the role and responsibility that all citizens have to guide the work of scientists and engineers by the decisions they make as workers, consumers, and citizens.

Do we need to have special courses to teach these core ideas?

The Framework provides a broad description of the content and sequence of learning expected of all students but does not provide grade-by-grade standards or specify courses at the high school level. There are many ways that these ideas can be combined and presented using a wide variety of media and learning activities. Schools are not asked to offer courses entitled “Engineering”
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or “Technology” any more than they are asked to offer courses with the title “Scientific Inquiry,” although they may certainly do so. And although the Next Generation Science Standards (Achieve, Inc., forthcoming) that will be based on the Framework will specify learning standards at a finer level of detail, it is not expected to recommend specific courses.

Will teachers need special training?
Many of the ideas about engineering and technology in the Framework will be familiar to today’s science teachers. Many science curriculum materials include practical applications of science concepts and provide design challenges alongside science inquiry activities. Subjects such as circuit electricity and simple machines, which fall squarely in the realm of technology, have traditionally been a part of the science curriculum.

However, there will be subtle but important differences that teachers will need to become aware of. For example, design challenges are commonly presented without specific instruction in engineering design principles. Although students may have a good time and come up with creative solutions, without specific guidance they are not likely to learn about the value of defining problems in terms of criteria and constraints, how to use the problem definition to systematically evaluate alternative solutions, how to construct and test models, how to use failure analysis, or how to prioritize constraints and use trade-offs to optimize a design. Consequently, it will take some time for curriculum developers and teachers to learn about the new features of the Framework and incorporate these ideas into their practices. Undoubtedly the process will be greatly facilitated by inservice professional development as well as modifications of preservice preparation programs for new teachers.

What will it look like in the classroom?
There are innumerable examples in existing curricula that illustrate engineering and technology instruction at all grade levels, many in conjunction with lessons in the natural sciences. An extensive database of materials with expert teacher reviews is available via the web at the National Center for Technological Literacy (2011), hosted by the Museum of Science in Boston. The free website, called the Technology & Engineering Curriculum (TEC) Review, provides a search engine that lets teachers search by grade level, topic, or science standards to find relevant materials.

Because selecting any one of the existing materials as an example would be unfair to all the others, I’ve chosen to close this article with an invented example, to illustrate how the teaching of science might be enriched with an engineering activity.

Imagine a physical science class in which students are being introduced to Newton’s third law, which states that every action has an equal and opposite reaction. The teacher blows up a balloon then lets it go. The balloon flies wildly around the room as air escapes out of the back end. The students are challenged to use Newton’s third law to explain why the balloon flew around the room. If the students understand the basic concept the teacher might go on to have students solve numerical problems involving Newton’s third law, or introduce a different topic.

Expanding on the lesson with an engineering design challenge is one way to introduce the relationship between science and engineering and to engage students in applying other concepts that they learned earlier in the year. Following the previous lesson, imagine that the teacher now asks the students to modify the balloon so that it flies more like a proper rocket—on a straight, predictable course, with as much speed and distance as possible—applying other appropriate science concepts learned previously.

Do they need to use the balloon the teacher gave them, or could they use one made from thicker rubber so they could increase the air pressure inside the balloon? Could they attach a straw and string to guide its path, or would the rocket need to fly freely? Teams would be urged to generate a number of design ideas and to evaluate them on the basis of the criteria and constraints of the problem. They would be urged to consider trade-offs as part of their planning effort; to test their designs, carefully controlling variables to determine which design works best; and to communicate the solution along with the test results that provide evidence in support of the optimal design.

Adding an engineering design challenge like the one previously described will add time to the lesson. That is not necessarily a bad thing if the science concept being
applied is important to teach and challenging for students to understand without concrete examples. There are also many other approaches to introducing engineering and technology into science lessons, such as conducting research on the internet or discussing relevant current events that require less time and may focus on more important issues. And, of course, not all science ideas lend themselves easily to engineering and technology connections.

No matter how carefully new curriculum materials are designed, however, some additional time will be needed for students to apply what they are learning to the real world. Today’s science curriculum is so packed that it is difficult to imagine how to add yet another set of ideas on top of what we have now. Consequently, our greatest challenge as a profession will not be whether or how to integrate engineering and technology into the curriculum, because most science educators have long considered these ideas to be an essential part of what they already do. Instead, the challenge will be how to make the difficult choices about what can safely be left out of the curriculum, so that we can do a better job of teaching core ideas and helping our students understand why they are important and how to apply them to real problems.

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Editor’s Note
The tables and page numbers referenced in this document refer to the “prepublication copy” of the Framework released in July 2011. A final published version will be released by the National Academies Press in late 2011 or early 2012 and will most likely have a different page-numbering system.

References

Kids’ Science Challenge

The first thousand entrants receive a free Science Activity Kit with hands-on projects related to this year’s topics.

How the competition works:
Open to students in grades 3 - 6. This year’s topics are Zero Waste, Animal Smarts and Meals on Mars.
Kids submit their ideas and experiments.
If their idea is chosen, they visit and collaborate with a scientist or engineer to see their idea come to life.

Other prizes include: science trips, kits and cool science toys.

Open for entries on October 1, 2011.
All entries must be received no later than February 29, 2012.

Made possible by the National Science Foundation

Check out kidsciencechallenge.com for:
• More information on the competition
• Lesson plans
• Videos and activities
• Online games and more!

12 Science and Children
OVERALL OBJECTIVES:

- Identify research-based practices and teaching strategies/projects where STEM education has been successfully integrated into the elementary and middle school curricula/programs;
- Identify outreach and informal projects where STEM education has been successfully integrated into after-school programs and informal education venues; and
- Identify STEM skills that are lacking in students at the high school/college levels.

Submit your proposal to one of the five strands listed below. Each strand has its own specific criteria.

1) PreK–2 (early childhood)
   a. Follow National Science Education Standards.
   b. Be developmentally and age appropriate.

2) Grades 3–5
   a. Identify effective strategies and resources that actively engage students.
   b. Help integrate components of STEM into the core elementary curriculum.

3) Grades 6–9
   a. Identify effective strategies and resources to help integrate components of STEM into the core middle grades curriculum.

4) Community/After-School/Outreach Program
   a. Demonstrate an outreach and informal project where STEM education has been successfully integrated into an after-school program and/or community outreach venue.

5) Administrators
   a. Describe and demonstrate how an administrator has effectively supported and built on STEM programs at his or her school or district.

All proposals must:

- Fit within a one-hour time period and actual presentations must be interactive.
- Be STEM oriented by showing an integrated approach to teaching and learning that removes the traditional barriers erected between the four disciplines and integrates them into one cohesive perspective of preK–8 instruction.
- Demonstrate best practices and/or teaching strategies/projects where STEM education has been successfully integrated into the elementary and middle school curricula/programs.
- Include research documentation validating success of specific program/curricula.
Call for Papers

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.

September 2012: Your Body and Health
Deadline February 1, 2012
In this time of being concerned about childhood obesity and good health, we are compelled to find ways to help children understand the importance of taking care of their bodies. Perhaps the first step is in developing an understanding of the human body. In what ways have you found it possible to develop an understanding concerning these questions?

• How do all of the parts of the body work together to help us move, respond, think, live?
• How does the body use the food we eat?
• Why is it important to get exercise, eat the proper foods, and get a full night of sleep?
• How can you stay healthy?
• What role do “germs” have in good health and how can we avoid catching a “bug”?

October 2012: Hard to Teach Science Concepts
Deadline March 1, 2012
Learning science is hard for many students, and we know that there are certain topics we face each year that are especially challenging. Identify some of the topics that are particularly difficult for students to comprehend. Many of these topics are difficult to teach due to student misconceptions/preconceptions. Begin with an explanation of how you go about identifying student understanding of the concept, then explain to our readers how you address the topic, and finally how you assess subsequent learning of those hard to teach concepts.

November 2012: Visual Literacy
Deadline April 1, 2012
Our students today receive a great deal of their information visually. This is largely due to their status as “digital natives.” It’s important to help them develop an understanding of how to “read” this information for comprehension. A picture cannot replace a thousand words if students don’t have the skills to interpret what they see. This visual literacy can also translate into a tool that students can use to help them develop conceptual understanding, anchor their knowledge, and communicate understanding. The use of items like charts, diagrams, photographs, graphic organizers, concept maps, graphs, and paper-folding techniques can all play a role in visual literacy instruction.

December 2012: Build it!
Deadline May 1, 2012
The properties of materials dictate how those materials can be used for creating new objects. Some objects occur in nature. while others are made by people from those materials. This can be a confusing concept for young children. But, once they have an opportunity to create materials, structures, and objects from other materials, they develop a clearer understanding. This understanding can be applied to engineering activities
and investigations. What types of activities have your students participated in that allow them to develop a conceptual understanding of the properties of materials and how those materials can be applied to fabricate new materials or objects? Most man-made objects are designed and created to solve a problem. What opportunities do you offer children to identify a problem, develop an item to solve the problem, and create that “invention”? Have you focused on students becoming design engineers?

January 2013: Focus on the New Standards
Deadline June 1, 2012
A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas is providing us with a glimpse into what we will find in the new generation of science education standards to be released in late 2012. The new standards will require teachers and curriculum experts to rethink our strategies and the science core ideas taught in our schools. Being informed through the Framework, we can begin considering learning progressions, embedding practices in core ideas, implementing engineering in instructional strategies, assuring the use and presence of crosscutting concepts, and integrating the three dimensions of the Framework (science and engineering practices, crosscutting concepts, and disciplinary core ideas). Have you studied the Framework as a professional learning community? Are you using the Framework to begin moving toward change? What strategies are you implementing to adjust what and how you teach? Has your school system or school started studies to understand what they are doing in light of the recommendations posed in the Framework? Are you personally changing what you do in your classroom? Provide our readers with suggestions concerning what you are doing that will help them take those initial steps in moving toward the new standards.

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.

Science Shorts
This column shares your take on classic classroom activities and how they emphasize science-process skills. After introducing the activity and placing it into classroom context, provide the activity how-to and materials list. Include a guiding question for the activity, the targeted grade level, and the process skills the activity addresses. Rubrics, study guides, worksheets, and other materials should be provided as they will be shared via NSTA Connections, our online resource site. Length: 1500 words

Methods and Strategies
This column provides ideas and techniques to enhance your 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

Recognizing Excellence
Have you been recognized for excellence? Share your experience with Science and Children readers! The column “Recognizing Excellence” will provide a peek into classrooms and programs that have received awards for their exemplary contributions to elementary science. It’s not just bragging (though you deserve it!). This column will provide models for your peers to follow as they create their own exemplary programs and inspire others to follow in your footsteps and gain recognition. Please see below for column guidelines for both individual teachers and science programs. Length: 2000 words

Find the complete 2011–2012 Call For Papers at www.nsta.org/sandcall.
Find manuscripts guidelines and submission instructions at www.nsta.org/elementaryschool.
Submit manuscripts at http://mc.manuscriptcentral.com/nsta.
PDI-1: Engineering by Design: An Integrative STEM Solution for K–12 (International Technology and Engineering Education Association)

PDI-2: Energy: What’s the Big Idea? Energy! (Center of Science and Math in Context, University of Massachusetts Boston)


PDI-4: The Literacy and Inquiry Connection: Instruction that Scaffolds and Enhances Scientific Thinking and Understanding (Seattle Public Schools)

PDI-5: Coaching: Knowledge that Works in Science Education Leadership (S2TEM Centers, South Carolina)

PDI-6: Conceptual Flow: Bridging the Gap between Standards, Instructional Materials and Student Learning (WestEd)

PDI-7: Inquiring Into Inquiry: Creating an Inquiry-based Classroom (Biological Science Curriculum Study)

PDI-8: What Works in Science Classrooms: Developing Student Understanding through Classroom Inquiry, Discourse and Sense-Making (McREL)

PDI Work Sessions are one-day standalone events that are in-depth professional development that do not have linked pathway sessions.

PDI-9 Work Session 1: Lecture Free Teaching: A Learning Partnership Between Science Educators and their Students (Bonnie Wood)

PDI-10 Work Session 2: Using Children’s Books to Guide Inquiry: Picture-Perfect Science (Karen Ansberry and Emily Morgan)

PDI-11 Work Session 3: Using Science Notebooks to Develop Conceptual Understanding in Grades K–8 (Connie Hvidsten)

Tickets available by pre-registration only

To view all offerings in detail, visit www.nsta.org/pd/pdi/2012indianapolis.aspx
New Roving Science Lab

It’s time to go back to Mars. Once every two years, the orbits of Earth and Mars are aligned just right, so it’s possible to send a spacecraft from here to there. That special time is now.

NASA’s latest mission, the Mars Science Laboratory (MSL), recently launched. It’s another six-wheeled rover, but much larger than the rovers Spirit and Opportunity that landed on Mars in 2004. They weighed under 400 pounds. MSL weighs nearly a ton and is about the size of a small compact car.

Another important difference between MSL and its predecessors is it doesn’t rely on solar panels for its power. Instead, it’s carrying 8 pounds of plutonium that gives off heat that is converted to electricity. The way MSL lands is also different.

John Grotzinger, project scientist for MSL, said Spirit and Opportunity “basically crash landed, softly with airbags,” but “Mars Science Laboratory is so large that we need an active propulsion system.”

The active propulsion system makes use of something NASA has never tried before. It’s a sort of a rocket-powered helicopter: When it gets to about 200 feet above the surface, it lowers the rover down on a cable. With the rover dangling below, it descends slowly until rover wheels touch the ground.

“The risks are obvious,” Grotzinger said, “but the advantages of this are that the rover lands basically intact, and there’s almost no subsequent setup that has to be done after the rover lands.”

The rover has a mast with a camera on it, and a robotic arm. But Grotzinger says MSL is not just about taking pictures and pulverizing rocks.

“It is a laboratory, and so within the belly of the rover are two very important instruments,” he said. “One of them is an x-ray diffractometer, which is the instrument that geologists use on Earth to characterize the mineral content of rocks and soils.”

The other instrument is called the Sample Analysis at Mars, or SAM. It’s actually a suite of instruments enclosed in a box about the size of a microwave oven. There are 74 sample cups inside SAM. The idea is that the rover’s robotic arm will drill into rocks, and some of the resulting powder will be delivered to one of the cups. The cup then goes into an oven, where it’s heated to 1,000°C.

“As the gases are coming off, we measure their composition with a mass spectrometer,” says Paul Mahaffy of NASA’s Goddard Space Flight Center. Mahaffy is the principal investigator for SAM.

One of the elements SAM will be able to measure is carbon. Carbon is essential for life, but Mahaffy and everyone else associated with this mission say finding carbon compounds will not be proof that there is or was life on Mars. It will be just another piece of evidence pointing in that direction.

“We fully don’t expect we’re going to go to Mars and get a definitive answer, ‘Yes, there was life,’ or ‘No, there wasn’t life,’ unless we absolutely happen to hit a home run and land in exactly the right spot, and conditions were exactly right,” Mahaffy said.
If everything had gone according to plan, MSL would already be on Mars. The mission was supposed to launch in 2009. But delays in building hardware forced a two-year postponement.

Mahaffy said the launch can’t come too soon for him and his team. “We’ve been anxiously awaiting the launch for a long time,” he said, “and even more anxiously awaiting August 6th of 2012, when we land in Gale crater and start exploring.”

Gale crater is MSL’s target. It’s a giant crater with a mountain in the middle of it. The site was chosen because measurements from Mars’s orbit showed there was lots of interesting geology in the crater, and possibly evidence that Mars was once habitable. With luck, MSL will provide confirmation of that.

http://n.pr/suXJPf (National Public Radio)

Oxygen and Earth’s Atmosphere

The appearance of oxygen in the Earth’s atmosphere probably did not occur as a single event, but as a long series of starts and stops, according to an international team of researchers who investigated rock cores.

The Fennoscandia Arctic Russia Drilling Early Earth Project (FAR DEEP) took place during the summer of 2007 near Murmansk in the northwest region of Russia. The project, part of the International Continental Scientific Drilling Program, drilled a series of shallow, two-inch diameter cores and, by overlapping them, created a record representing stone deposited during the Proterozoic Eon—2,500 million to 542 million years ago.

Lee R. Kump, professor and head of geosciences at Penn State, said it has been thought that oxygen came into Earth’s atmosphere quickly during a single event.

“We are no longer looking for an event,” he said. “Now we are looking for when and why oxygen became a stable part of the Earth’s atmosphere.”

The researchers report in a recent issue of Science Express that evaluation of these cores and comparison with cores previously analyzed by others supports the conclusion that the Great Oxidation Event played out over hundreds of millions of years. Oxygen levels gradually crossed the low atmospheric oxygen threshold for pyrite—an iron sulfur mineral—oxidation by 2,500 million years ago and the loss of any mass-independently fractionated sulfur by 2,400 million years ago. Then oxygen levels rose at an ever-increasing rate through the Paleoproterozoic, achieving about 1% of the present atmospheric level.
In Brief

- A distant planet, barely bigger than Earth, has been discovered. NASA’s orbiting Kepler probe initially detected the super-Earth—a rocky planet about 1.6 times the size of the Earth—in our Milky Way galaxy about 350 light years from our solar system. Overlapping readings taken by two ground-based telescopes at the Kitt Peak National Observatory in Arizona confirmed the discovery. Discovering a relatively small, Earth-size planet so far away is remarkable because usually only distant planets at least as big as our solar system’s monstrous gas-giant, Jupiter, can be detected; Jupiter has nearly 320 times more mass than the Earth, with 120 times more surface area. The newly discovered planet also streaks around its bright star in just 2.8 days, and orbits from a distance of 6 million kilometers, making it more difficult to track and identify. NASA scientists emphasize that just because a planet is categorized as a super-Earth does not mean it is Earth-like. They say the newly found super-Earth is heavy and dense, with a mass no more than 10 times that of Earth. It has a surface temperature of 1,630°C, which is hot enough to melt iron. In contrast to the planet’s brief 2.8-day year and scorching proximity to its star, Earth is a comfortable 150 million kilometers away from the Sun, and takes a leisurely 365 days to make a complete solar orbit. [http://bit.ly/rLukbk](http://bit.ly/rLukbk) (Voice of America)

“...”

Adding Arts to STEM

The acronym STEM—shorthand for science, technology, engineering, and mathematics—has quickly taken hold in education policy circles, but some experts in the arts community and beyond suggest it may be missing another initial to make the combination still more powerful. The idea? Move from STEM to STEAM, with an A for the arts.

Although it seems a stretch to imagine STEM will be replaced in education parlance, momentum appears to be mounting to explore ways that the intersection of the arts with the STEM fields can enhance student engagement and learning, and even help unlock creative thinking and innovation.

In fact, federal agencies, including the U.S. Department of Education and the National Science Foundation (NSF), are helping to fuel work in those areas.

The NSF has provided research grants and underwritten a number of conferences and workshops around the nation this year, including a forum hosted by the prestigious Rhode Island School of Design, titled “Bridging STEM to STEAM: Developing New Frameworks for Art–Science–Design Pedagogy.”

Picking up on the Rhode Island institution’s push for STEAM, in late September, a lawmaker from that state, U.S. Rep. James Langevin, a Democrat, introduced a House resolution to highlight how “the innovative prac-
tices of art and design play an essential role in improving STEM education and advancing STEM research.”

On-the-ground examples of bringing the arts and STEM learning together abound, from Philadelphia and San Diego to Dayton, Ohio. For example, the Philadelphia Arts in Education Partnership, with support from a $1.1 million Education Department grant, is working with city schools to help elementary students better understand abstract concepts in science and mathematics, such as fractions and geometric shapes, through art-making projects.

One advocate of the STEM to STEAM push is Harvey Seifter, the director of the Art of Science Learning, a project financed by an NSF grant that organized three conferences last spring in Washington, Chicago, and San Diego. They brought together scientists, artists, and researchers, as well as educators, business leaders, and policy makers to explore how the arts can be engaged to strengthen STEM learning and skills and produce a more creative American workforce. Seifter is also an expert in arts-based learning who consults with Fortune 500 companies on fostering business creativity.

“For me, it is about connecting—or reconnecting—the arts and sciences in ways that learning can happen at the intersection of the two,” Seifter said. “We believe there is a powerful opportunity here to use the arts and arts-based learning to spark transformational change in science education.”

One core idea Seifter and other STEAM advocates emphasize is that the arts hold great potential to foster creativity and new ways of thinking that can help unleash STEM innovation.

“There is creativity in STEM itself, super genius in it ... but in arts education, it really is the raison d’être to be out of the box, to accept the chaos,” said John Maeda, the president of the Rhode Island School of Design, in Providence.

Artists and designers, he said, are “risk takers, they can think around corners.”

Maeda invokes STEAM as a pathway to enhance U.S. economic competitiveness, citing as an example the late Apple cofounder, Steve Jobs, a leading force behind the iPod, iPhone, and other electronic devices.

“What STEAM means, it should feel like Steve Jobs, what he did for America,” Maeda said. “It is an innovation strategy for America.”

But some experts perceive a special connection between the arts and the STEM fields. Seifter, for example, points to a 2008 study led by Robert Root-Bernstein of Michigan State University, which found that Nobel laureates in the sciences were 22 times more likely than scientists in general to be involved in the performing arts. Others note that Albert Einstein was an accomplished violinist. And then there’s the Renaissance figure who some view as the personification of STEAM: Leonardo da Vinci, the Italian painter and sculptor who also made a name for himself as a scientist, engineer, and inventor.

Whether integrating the arts with STEM education enhances student learning is not a settled matter, as even advocates like Seifter are quick to acknowledge.

“There is no question, to me, the critical missing piece is the data,” Seifter. He adds that even as he’s witnessed the power of the intersection, he sees a critical need for a “solid body of empirical knowledge about what the arts bring to the STEM equation.”

Indeed, research examining the effect of arts integration on student achievement across academic disciplines appears to show mixed results. Leaving the research question aside, however, some experts stop short of embracing a change from STEM to STEAM.

Alan J. Friedman, a former head of the New York Hall of Science, said it’s crucial for students not to lose sight of the differences, for example, between art and science.

“One crucial point at which they part ways is the act of deciding, ‘Is it good art? Is it good science?’” said Friedman, a member of the National Assessment Governing Board who holds a doctorate in physics.

“Science and art have a lot to learn from each other, a lot of inspiration to share, a lot of commonality. They also have some very essential differences that are at the core of what they are, which is why I have trouble with STEAM.”
Susan R. Singer, a biology professor at Carleton College in Northfield, Minnesota, who previously served on the National Research Council’s Board on Science Education, echoed the point.

“Not to devalue the symmetry, but they are very different ways of knowing the world,” Singer said. “I would stop short of STEAM, but celebrate the ways that they work together.”

What the intersection of the arts with STEM learning looks like in practice varies widely.

The Philadelphia Arts in Education Partnership is focused on math and science instruction in the elementary grades, with support coming from its four-year grant from the Education Department’s Arts in Education Model Development and Dissemination program. For example, through art-making projects, students at one school manipulated the abstract concepts underlying fractions for a more concrete understanding of how they work. The students even created a “fraction mural” displayed at the school.

“We match arts skills and processes to a specific learning goal in math and science,” said Raye Cohen, the education director at the Philadelphia arts group.

Cohen said the project involves an “intense research component” and will look at a variety of effects, including student test scores and suspensions and unexcused absences, as well as parent engagement in homework and changes in teaching practices.

According to Cohen, that work with the visual arts is especially promising.

“Visual arts just seems to really be able to home in on the concept, taking it from the abstract to the concrete, so students are really able to understand it,” she said.

(Education Week)

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Gravity and Weight

By Emily Morgan and Karen Ansberry

What goes up must come down…as long as you aren’t floating in space, that is! This month’s column explores the concept of gravity. In the lesson for grades K–2, students explore gravity through several activities and readings, and learn that the force of gravity is what gives things weight. In the lesson for grades 3–6, students predict how different games and toys would work without gravity and then check their predictions by watching videos of the toys and games in action on the International Space Station (ISS) and the space shuttle.

This Month’s Trade Books

I Fall Down
Written by Vicki Cobb.
Illustrated by Julie Gorton.
Grades K–3

Synopsis
From the Vicki Cobb Science Play series, this book uses a stop-and-try-it format to explore the basics of gravity.

Floating in Space
Written by Franklyn Branley.
Illustrated by True Kelley.
Grades 4–6

Synopsis
This book from the Let’s-Read-and-Find-Out Science series describes how astronauts deal with weightlessness.

Curricular Connections

The National Science Education Standards suggest that early elementary students’ understanding of force and motion concepts be developed primarily from manipulating objects and describing their motion. This month’s book for grades K–2 poses questions that can be answered by doing activities like dropping objects and observing them fall. After students explore, the book provides an explanation. Some key concepts include: gravity is always pulling things down; as long as you’re on Earth, you can’t get away from gravity; and gravity gives things weight. In the upper elementary grades, the Standards suggest that students describe the specific forces affecting the motion of an object. To get students thinking about this, the second lesson for grades 3–6 suggests that they try some simple toys and games. Students then predict how the toys and games would work in a weightless environment: the space shuttle or ISS. To check their predictions, the students watch online video segments of the toys being demonstrated in space by astronauts and cosmonauts in the shuttle and ISS. One common misconception about the weightless environment in the space shuttle or ISS is that there is no gravity. Actually, it is Earth’s gravity pulling on these spacecraft and everything inside that keeps them in orbit. As they orbit Earth, they are in a state of free fall, which makes everything feel weightless. This concept of the shuttle and space station being in free fall during orbit might be too difficult for some elementary students to understand, so instead of explaining this, we simply refer to the people and objects in the shuttle and ISS as experiencing “weightlessness.”

Karen Ansberry (karen@pictureperfectscience.com) is a science curriculum leader at Mason City Schools in Mason, Ohio. Emily Morgan (emily@pictureperfectscience.com) is a consultant for Picture-Perfect Science in West Chester, Ohio. They are the authors of Picture-Perfect Science Lessons and More Picture-Perfect Science Lessons, available from NSTA Press.

Reference
Engage
Tell students that on the count of three, you want them to jump as high as they can. Count “1, 2, 3, jump!” Then ask, “Why do you think you always come down after you jump?” Have students turn and talk with a partner and then share their ideas with the class. Tell students that they will be learning about why they always come back down after they jump up by reading a book and doing some fun activities.

Explore/Explain
Prior to reading I Fall Down, decide which activities you will stop and try during the read aloud and then have those supplies handy. Depending on the age of your students, you may decide to do some of the activities as demonstrations and others as whole-class activities.

Show students the cover of I Fall Down. Ask them to signal when they hear the answer to the question “What makes things fall?” Students should signal when you read page 10, which says, “Know what makes things fall? It’s a force called gravity.” Continue reading the book aloud, stopping to try the different activities, and then read the explanations on the following pages.

Elaborate
Reread pages 10 and 11 of I Fall Down, which explains that as long as you are on Earth, gravity is always pulling things down. Tell students that you are going to take them to the playground to see how gravity affects them when they play. When you get to the playground, have students sit together where they can look at the playground equipment. Have a student go down the slide and ask, “What pulled him down the slide?” Have another student throw a ball high up in the air and ask, “What pulled the ball back down to the ground?” Continue to demonstrate gravity with other things on the playground, being sure to use the word “pull” so that students understand that gravity is a pulling force.

Evaluate
Back in the classroom, ask students to finish the sentence, “Gravity pulls…” and create an illustration to go with it. For example, “Gravity pulls me down the slide.” “Gravity pulls syrup onto my waffle.” “Gravity pulls my paper airplane to the ground.” Display all of the sentences and pictures on a bulletin board titled “Gravity Pulls.”

Connecting to the Standards
This article relates to the following National Science Education Standards (NRC 1996):

Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry (K–8)

Standard B: Physical Science
- Position and motion of objects (K–4)
- Motions and forces (5–8)

Grades 3–6: Toys in Space

Engage
As a preassessment of your students’ background knowledge of gravity, show them a clip of a hockey game and ask them how Earth’s gravity affects the game of hockey. They should realize that gravity pulls the puck to the ice, holds the players down, and basically pulls everyone and everything toward the ground. Then ask, “How do you think the game of hockey would work in space?” Have them turn and talk to a partner. Tell students that astronauts wondered the same thing, so in 2002, they brought a hockey puck and hockey sticks to try out on the ISS. Show them the “International Toys in Space” video online that shows astronauts and cosmonauts in the ISS playing hockey (see Internet Resources). Discuss how the game worked differently in the weightless environment of the ISS than it does on Earth, and how the astronauts and cosmonauts adapted the game to make it work better in weightlessness (e.g., they strapped their feet to the wall, put the puck over the vent).

Explore
Set up stations around the classroom with various toys from the Toys in Space project, such as a gyroscope, magnetic Whee-Lo, Yo-Yo, jacks, paper airplane, paddleball, Slinky, marbles, and spinning top. Give each student a copy of the Toys in Space student page (see NSTA Connection). They should play with the toy at each station, think about how Earth’s gravity affects the way it works, and predict how it worked when astronauts tried it on the ISS or space shuttle. Have students share their predictions.

Explain
Show the video clips of astronauts using the same toys on the ISS or space shuttle. Students should record how the toy really worked in weightlessness and compare it to their prediction. Next, read Floating in Space aloud, which explains more about weightlessness and how astronauts deal with it as they work, eat, and sleep. Have students listen for strategies and tools astronauts use to help them work in a weightless environment (e.g., Velcro, straps, bungee cords, attaching things to the walls).

Elaborate
Have students choose one of the toys that didn’t work well in space and write a paragraph explaining why it works differently in weightlessness. Then, have them write or draw their ideas on how the toy could be modified to perform better in weightlessness. They can incorporate ideas that the astronauts used in the book Floating in Space.

Evaluate
Have students choose one of their favorite toys or games and create a version of it that would work in weightlessness. They can create new rules or strategies, draw pictures of how it would work, and even give it a new name. Have them share their new toys or games with the rest of the class at a “Space Games” convention.

Internet Resources
Resource Component for Toys in Space
http://aesp.nasa.okstate.edu/ftp/anderson/toysweb/index.htm
Toys in Space DVD
http://corecatalog.nasa.gov/item.cfm?num=009.0-11D

NSTA Connection
For a Toys in Space student page, visit www.nsta.org/SC1201.
Elementary Extravaganza

Mark your calendars!

- Friday, March 30, 2012 • 8:00–9:30 AM
- 500 Ballroom, Indiana Convention Center

This Extravaganza at the NSTA 2012 Indianapolis National Conference on Science Education (March 29–April 1, 2012) is not to be missed! Join elementary groups of professionals for an exceptional opportunity. Gather resources for use in your classroom immediately. Engaging hands-on activities, strategies to excite and encourage your students, a preview of the best trade books available, information about award opportunities, contacts with elementary science organizations, sharing with colleagues, door prizes, and much more will be available to participants. Walk away with a head full of ideas and arms filled with materials.

Organizations participating in the Elementary Extravaganza include the Association of Presidential Awardees in Science Teaching, the Council for Elementary Science International, the NSTA Committee on Preschool–Elementary Science Teaching, Science and Children authors and reviewers, and the Society of Elementary Presidential Awardees.

* Coffee, rolls, door prizes, and more!

Looking Toward the New Framework

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Sample Sessions

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- Weaving a Web of Reading and Writing Science: Strategies for Science Literacy That Stick

To view all offerings in detail visit www.nsta.org/rdc2012.aspx.

Pre-register for this ticketed event at www.nsta.org/rdc2012.*

*Registration to the national conference is required.
Spotting the Moon in the sky is like finding a treasure—unexpected and beautiful. When children look for the Moon in the sky, they don’t know where to look. This is true of many adults, too. A few months of daily “Moon Observation Journaling” will reveal the pattern of changes in appearance and position and lead to understanding that there is a relationship—the Moon does not appear at random times.

If we look closer with binoculars or a telescope, or through a photograph or video, we see the Moon’s body is round like a sphere, and the surface is covered with many circular shapes. These circles are called impact craters (see Internet Resources). The craters form when pieces of another body in space, such as an asteroid or comet, hit the surface of a planet or a natural satellite (Moon). Those on the Moon are easy to see because, unlike on Earth, there is no weather to make changes to the surface.

The Moon is far away and most easily observed at a time when most young children are sleeping. Because direct contact isn’t possible, adults have to be creative in how they help children learn about the Moon. Even a single night of Moon viewing guided by an interested adult can support the development of young children’s curiosity and their image of themselves as explorers of the natural world beyond Earth.

I remember when my father took me and my sisters outside (later than our bedtime) to see the Moon using an old telescope. The telescope view made the Moon appear to be within reach, so bright and detailed, and suddenly, so real.

We can help young children begin to understand one of the reasons for the patterns we see on the Moon’s surface by modeling the process that creates impact craters. Understanding about such Earth and Space science processes is part of the National Science Education Content Standard D (NRC 1996).

Making impact craters in sand by dropping several balls of different weights can be a simple activity for students to learn that craterlike shapes are formed in the sand. It can be expanded into an activity in which relative measurements are made, comparing the size of the ball, the size of the resulting crater, and the height from which the ball is dropped and the depth of the crater. This column describes a simple crater formation activity, but you can add measurement depending on the readiness of your class.

Support children’s developing language arts skills by holding discussions for oral language practice and introducing new vocabulary—crater, circle, sphere, and impact. Have children document the process of crater formation with drawings or photographs so they will look closely and think about the pulling force (gravity) that brought the dropped balls into the sand and the pushing force of the ball that moved the sand into the crater shape. For younger children, this activity teaches about using models to understand Earth Science processes. Older children may also begin to think about force by comparing craters made by different weight balls, and the push the children give them.

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

Reference

Internet Resources
Earth’s Moon: Overview
http://solarsystem.nasa.gov/planets/profile.cfm?Object=Moon
Impact Craters—Holes in the Ground!
http://solarsystem.nasa.gov/docs/Impact_Craters_Holes_508FC1.pdf
Crater Making
Adapted from Thinking BIG, Learning BIG: Connecting Science, Math, Literacy, and Language in Early Childhood (Evitt, Dobbins, and Weesen-Baer 2009).

Objective:
To explore the formation of impact craters.

Procedure:
1. Prepare the outside area or indoor tub of sand or baking soda. Test the activity beforehand to be sure the sand or baking soda will hold an impression of a ball dropped into it.
2. As a group, view a photograph of the Moon and discuss its appearance. If possible, view a high resolution photograph on a large screen so details are easily seen.
3. Take notes of the children’s ideas and descriptions of their previous experiences and knowledge about the Moon. Children may say, “I see circles!” “What made the craters?” “Why is part of the Moon light-colored and part of it dark?”
4. Ask the children, “Can you think of a way that we can make craters in some material?” Help the children plan the setup, including the use of goggles, by asking open-ended questions such as, “What could we do to make big craters and small craters?” and “How can we protect our eyes from any sand that gets thrown into the air?”
5. Have the children handle the balls and weights and predict what kind of impact crater each one might make. Emphasize the importance of simply dropping the balls from the same height (without throwing or pushing them down) to form craters, so that the size and weight of the balls will be the only different factor to affect the size and depth of the craters. (After the first tries you can add the force of the throw/drop as a variable.)
6. Have the children stand and drop a ball from shoulder height into the sand. At first the children will all want a turn and will want to make the biggest, deepest crater. After their first tries they become more interested in discovering how to make craters of different sizes and depths.
7. After each impact, have children remove the object and smooth the sand surface with a tongue depressor or piece of stiff cardboard to prepare for the next impact.
8. Challenge the children to measure the crater sizes and depths, and document how they were made by making a chart or drawing pictures and dictating the procedure. Ask, “Is there a way you can make a smaller/larger, or deeper/more shallow crater?”

The children may become interested in how impressions of all kinds are made in various materials. Continue this exploration using modeling clay, potter’s clay, and other dough or clay types, comparing the force needed to push and shape different materials.

Reference

NSTA Connection
For more resources, visit the Early Years blog at www.nsta.org/EarlyYears.
The familiar adage “seeing is believing” implies that children will recall a particular phenomenon if they had the experience of seeing it with their own eyes. If this were true, then most children would believe that you could see the Moon in both daytime and at night. However, when children are asked, “Can you see the Moon in the daytime?” many will say “no,” even though they have actually seen the Moon many times in the morning or afternoon sky. The formative assessment probe, “Objects in the Sky” (Figure 1) shows how persistent the belief is among elementary-age children that the Moon can only be seen in the nighttime (Keeley, Eberle, and Tugel 2007).

**Learning Goals**

Understanding where the Moon is located at different times of the day and its changing appearance as viewed from Earth are important goals for learning. In the early elementary grades, the Benchmarks for Science Literacy state that by the end of second grade, students should know that “the Sun can be seen only in the daytime, but the Moon can be seen sometimes at night and sometimes during the day. The Sun, Moon, and stars all appear to move slowly across the sky” (AAAS 2009). The newly released A Framework for K–12 Science Education (NRC 2011) states that by the end of second grade, students should understand that “Patterns of the motion of the Sun, Moon, and stars in the sky can be observed, described, and predicted.” Building on this earlier idea, by the end of fifth grade, students should understand, “The orbits of Earth around the Sun and of the Moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily and seasonal changes in the length and direction of shadows; phases of the Moon; and different positions of the Sun, Moon, and stars at different times of the day, month, and year.”

To achieve an understanding of these important learning goals, elementary students should have the opportunity to observe the position and phases of the Moon in both the daytime and nighttime sky and discover the cyclic pattern of Moon phases by analyzing their recorded observations. This experience is one of several critical prerequisites to constructing an explanation for the phases of the Moon. Before students engage in monthly observations to discover the pattern of Moon phases, consider using a probe such as “Objects in the Sky” to find out whether students recognize that the Moon can be seen in the daytime.
With Their Own Eyes

Parts of this probe are based on research conducted on children’s ideas about the Moon. Vosniadou and Brewer (1994) found that many young children believe that the Moon is only visible at night and the occurrence of the Moon in the sky is associated with nighttime. Some students will even attribute the appearance of the Moon as a causal factor for night. Research has also revealed that some students believe the Moon rises straight up in the evening, stays at the top of the sky throughout the night, and then sets straight down (Plummer 2009). When children are asked why they think the Moon is only visible at night, they often explain their thinking using this “up–down rule” and may even confuse it with the rising and setting of the Sun.

Do these ideas change with age? Consider using the “Objects in the Sky” probe or asking the question, “When do you see the Moon: daytime, nighttime, or both?” across multiple grades from first- through fifth-grade. Share your data and look for differences in students’ ideas. Probe further to find out why students think the Moon is only visible during the evening. If students believe the Moon can be seen in the daytime, probe to find out what phases they think can be observed during the day. Consider other factors that may have influenced their thinking that the Moon is visible only in the nighttime. For example, children’s storybooks, trade books, and instructional materials almost always show the phases of the Moon in a dark, nighttime sky. Instead of telling students that the Moon is visible in the daytime, take them outside during a phase when it is visible in the morning or afternoon sky and let them see it for themselves. Continue making daytime observations of the Moon, when visible, to reinforce that we can sometimes see the Moon during the daytime. Have students record the time and position of the Moon in the daytime sky and the phase present.

This probe points out that when students have seen something, they don’t necessarily believe it. By confronting students with their idea that the Moon is only visible at night through a direct experience of observing the Moon during the daytime, you may help your students give up their misconception. Furthermore, the probe is formative in nature by pointing out the importance of not limiting students’ observations to a nighttime context. When the Moon is visible during the school day, encourage students to make their monthly observations then, as well as in the evening (which is necessary for them to see the full Moon because it rises when the Sun
sets and sets as the Sun rises). By using this probe, perhaps you will see the old adage change to “believing is seeing!”

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A bunny rabbit playfully hops across the wall. Then hands realign and fingers shift to make a hawk soar toward the ceiling. Most children have enjoyed the delightful experience of playing with shadow puppets. We build on this natural curiosity to help students link shadows to complex astronomical concepts such as seasons. The following inquiry-based lessons come from our work with fourth- and fifth-grade children as they investigate properties of shadows.

Shadow Misconceptions

Students frequently have an incomplete understanding about shadows. Some of the common misconceptions include that shadows exist independent of light sources and may come out of or be projected from a person, animal, or object. Some students think that shadows are always present but need light to illuminate them to be seen. Other students believe that reflected lights or clouds are involved in creating shadows. Some students even give shadows human attributes, believing that shadows can willfully follow a person around or be cowardly and hide when afraid (Eschach 2003).
Daily Shadow Changes

On a sunny day, students can venture outside and directly observe their own shadows. This activity works best if students are directed to select a location that will not be cast in shadow by buildings or large plants at any time during the day. Students must stay in the designated area at all times and be instructed to never look directly at the Sun.

Working in pairs, students select an observation spot, draw a circle around their feet with chalk, and write their names inside the circle so they can find the same location later in the day. The cardinal directions (N, S, E, and W) are marked on the perimeter of the circle. Students take turns tracing their shadows with chalk at 10:00 a.m., noon, and 2:00 p.m., and they put an x along with the time to indicate the direction of the Sun. In their journals, students draw a diagram of their observations, noting which direction their shadow “pointed” at each time of the day along with the direction of the light source, the Sun. After data are gathered, we ask students productive questions to help them see patterns in their data (Elstgeest 2001). Productive questions are those that children can answer through their own observations and related data. Examples include:

- What do you notice about the shadows throughout the day? What happens to the length of the shadow throughout the day? (It changes length, getting shorter from morning to noon and then longer from noon to afternoon.)
- What happens to the direction of the shadow? (It changes.)
- Where is the shadow located relative/compared to the Sun? (Always opposite the Sun.)
- At what time was the Sun out/visible and there was no shadow at all? (Never in our data.)

Find additional information on productive questions and specific examples of each question type online (see NSTA Connection).

The next day, a slightly more abstract version of the same activity is conducted. Pairs of students are given 1 oz of modeling clay, a pencil, a large piece of white paper, and a flashlight. They poke the pencil into the modeling clay vertically and place it on the center of the paper. While imagining the table being the Earth’s surface or the horizon, they shine the flashlight in an arc over the pencil. They trace the resulting shadows cast at 6:00 a.m. (at the table level), 9:00 a.m. (above the pencil), 3:00 p.m., and 6:00 p.m. (at the table level) on the large white paper. Again, we conclude with questions:

- What do you notice about the shadows at different positions or angles of the flashlight? When were the shadows the longest? (When the flashlight is at the table level.)
- The shortest? (When the light is above the pencil.)
- Where was the shadow located relative to the flashlight? (Always opposite.)

Students are encouraged to note their analyses in writing. Next, the children compare this data set with the shadows they observed outside. To focus their analyses, we ask:

- How do these shadows compare to the ones from the playground? Based on your observations, what do you need to make shadows? (light source, an object to block the light, and surface to cast the shadow onto)
- What are the light sources in the two investigations? (Sun and flashlight)
- Where is the light source relative to the object when the shadows are the longest? (low in the sky or near the tabletop)
- Where is the light source when the shadows are the shortest? (highest above the horizon or tabletop)

We introduce the terms **azimuth** and **altitude** as concept labels for their observations. **Azimuth** is the term used to describe the cardinal position of the Sun at a point in time, which is related to the shift in the direction of shadows on the playground and to variations in the path of the arc that they traced with the flashlight. In this case, **altitude** means how high the light source or Sun is from the horizon or tabletop. Using the observer as the vertex, students can qualitatively observe an angle between the Sun and a point directly below the Sun on the horizon and describe the angle in terms of how high the Sun is in the sky relative to the horizon. This actual measurement is altitude, and later in the lesson the children will use planetarium software to make and record these measurements. At this point they can qualitatively describe how high the Sun is relative to the horizon (in the morning and evening the Sun is closer to the horizon and the angle is smaller than at lunchtime when it’s highest in the sky and the angle is the biggest). Depending on the ages and abilities of the students, they can estimate the angle of the altitude by placing one fist at the horizon and the other over the light source (flashlight). A partner can look at the angle the first person’s arms make and estimate the angle (about 15°, less than 45° but greater than 15°, greater than 45° but less than 90°).

We ask students to look at their data to see how the length of a shadow is related to the angle of the altitude (smaller angles, longer shadows; greater angles, shorter shadows). Next, we ask students to infer how this information corresponds to shadows at sunrise, sunset, and noon.
Students may apply their learning by making sundials and gathering daily data, which they then compare throughout a week or month. See Internet Resources for directions on how to make and use a sundial.

Advanced students may extend their knowledge of proportions and link the information to their observations of shadows. See Internet Resources for a lesson plan on how to use students’ observations and measurements of the heights and shadows of familiar objects. They then apply this information to indirect measurement to find the heights of things that are much taller, like trees and a flagpole.

Seasonal Shadow Changes

The lengths of shadows vary not only by time of day, but also by season and latitude. In the northern hemisphere at the same time of the day, winter shadows are longer than summer shadows because of the difference in the angle of Sun rays striking Earth (see Internet Resources for a more detailed explanation).

We remind students that the lengths and directions of shadows change throughout one day based on the position of the Sun in the sky. Then we ask them how they think shadows might change from season to season. The students test their predictions by plotting the apparent path of the Sun across the sky in each of the seasons.

We use the planetarium software program Starry Night (version 5.0, Imaginova) to explore seasonal changes in the Sun. Children access sky data at various times of day, days of the year, and calendar years, which allows for more efficient use of classroom time than engaging in real-time natural observations. Students can easily collect data related to a specific question, record the data on a chart, and then analyze the data by looking for patterns. To gather the data, students open the software program and select the targeted date and desired geographic location from the toolbar. Then they double click on the Sun, which produces a pop-up box with the times of sunrise, sunset, and transit, as well as the altitude and azimuth information for that particular time, date, and location.

The students use Starry Night to gather data on the apparent path of the Sun each season. (The same data are available from astronomical data charts; see Internet Resources.) Each student is given a Sun observation data recording sheet. They look up altitude, azimuth, and transit of the Sun and also total number of daylight hours for each of the following dates: March 21 (Spring Equinox), June 21 (Summer Solstice), September 21 (Fall Equinox), and December 21 (Winter Solstice). They record the values on an enlarged class chart. Next, students plot the chart values on graphs. By manipulating the software, they add additional data points for several times during the day: 8:00 a.m., 10:00 a.m., noon, 2:00 p.m., and 4:00 p.m. The y-axis indicates the altitude of the Sun at the times recorded and the x-axis charted the azimuth. Students use different-color pencils to plot the data on the graph (e.g., red = June 21, brown = September 21), which makes it easier to compare data across the seasons.

For older or advanced students, teachers may also introduce the analemma curve and how to use it to calculate the exact time of high noon in any location. (See the NASA classroom activity, Reinventing Time, listed under Internet Resources, for additional information.)

The Sun path chart is enlarged to poster size so that students can plot their data for whole-class discussion. The resultant graph shows strikingly different Sun paths by season. The path of the summer solstice is much higher than the winter solstice. The spring and fall equinoxes follow the same path.

To facilitate data analysis, students were asked the following productive questions:
What do you notice about the path of the Sun throughout the seasons? (The shape of the path [an arc] and the direction of the path [generally from East to West] are similar from season to season. The biggest arc is in the summer with the smallest in the winter. The spring and fall paths are similar or about the same to each other and larger than the winter but smaller than summer paths.)

How does the altitude of the Sun on each of the four dates at noon compare? (The Sun’s altitude is highest during summer and lowest in winter. The altitudes during spring and fall are between the measurements of summer and winter.)

How do the Sun data compare between December and June? (The Sun is higher in the sky and visible for more hours during June than in December.)

Infer the comparative lengths of shadows at 3:00 p.m. on each of the four days. Which season is likely to have the longest shadows at this time? The shortest? Why? (The shadows will be the longest in winter/December compared to the other seasons because the Sun will be lowest in the sky at 3 p.m. The shadows for summer/June will be the shortest because the Sun will be highest in the sky.)

What can you infer about how the Sun’s patterns in summer and winter affect the temperature? (Because the Sun is higher in the sky in the summer, the Sun’s light hits the Earth more directly. Also, the Sun is visible in the sky for more hours during summer. Both of these things will make the temperatures warmer in the summer than in the winter).

At first, the students are surprised to see the different paths of the Sun. They do not anticipate how different the data will be from one season to the next. They especially are surprised to see that the paths were the same in the autumn and spring!

During discussion, the terms summer/winter solstice and autumn/spring equinox are introduced to name the periods of time represented on the chart. The changes in altitude and azimuth are linked to the tilt of the Earth and the subsequent changes in the slant of the Sun rays striking the Earth in each season. In the northern hemisphere, the most direct Sun rays strike the Earth during the summer. This is similar to holding the flashlight directly over the pencil in the investigation, which resulted in short shadows. By comparison, the Sun’s rays strike the Earth in a more oblique angle in winter, resulting in longer shadows. Most of the students grasp the concept of the tilted Earth causing seasons and varied shadow lengths, but some retained their inexperienced views.

To enhance the inquiry experience, students can share their data online as part of the Sun Shadows Project (see Internet Resources), or they may simply access shadow data from the system to compare different geographic locations. They may also create a school-year record of how shadows change throughout the seasons. They may revisit and extend their real-world observations by making monthly observations of their traced shadows on the playground. A digital record will facilitate comparisons across the months.

Assessing Learning

To assess students’ understanding of shadows, we read Robert Louis Stevenson’s poem “My Shadow” in which a child describes some curious observations of shadows (see Internet Resources). We make a class list of what the child in the poem thinks about shadows, which consists of the following:

- Shadows look like the objects that make them (He is very, very like me from the heels up to the head).
- Shadows can move in front of us (And I see him jump before me, when I jump into my bed).
- Shadows can change size (For he sometimes shoots up taller… And sometimes gets so little…).
- Shadows can go away altogether (... there’s none of him at all).
- Shadows can stay near the object that casts them (He stays so close beside me… as the shadow sticks to me).
- Shadows are cowards (...he’s a coward you can see…).
- Before the Sun is up, there are no shadows (...be-
fore the Sun was up…my lazy little shadow… had stayed at home behind me).

Some students may have difficulty generating contributions for this list. Dependent on the students’ needs, we ask productive questions to stimulate their thinking. What does the child observe about the shape of the shadow? What shape does the shadow have? Where is the shadow in the poem located, behind or in front of the child? What does the child observe about the size of the shadow? About how often does the child have a shadow? Does the child always have a shadow? At what times in the poem does the child have no shadow? Where is the shadow located relative to the child? What human traits or emotions does the child attribute to shadows?

After making the class list, we have the students work with a partner to compare how their own data and observations fit with the child’s observations. Which of the attributes in the poem are supported with our data? Which are not?

Conclusion
Providing opportunities for students to control a light source, giving them time to systematically explore with objects, and guiding the analysis of data with productive questions leads to greater understanding of the targeted concepts. By building on initial investigations with more complex ones, students are encouraged to examine what they already believe about shadows. Furthermore, linking data about the Sun to both shadow length and seasonal change encouraged students to support their thinking with data. Collecting data with Starry Night is highly engaging and efficient, and it helps students construct valuable content knowledge as well as develop inquiry skills.

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Helping students understand the complex relationships between our planet, our nearest star, and our only satellite is a challenging task. It can be difficult to teach students about objects in space that are far away and impossible to touch. In fact, even many teachers have difficulty explaining the reasons for seasons (Küçüközer 2008). We found that reading nonfiction trade books, modeling relationships using everyday objects, and synthesizing ideas through writing and drawing helped our students improve their understanding. An added benefit of the integration was that teaching about the solar system during language arts freed up time in our schedule to introduce students to the complex world of engineering in science class. While designing and building “Mars landers,” fourth-grade students engaged in important engineering practices such as making models, testing designs, and comparing the effectiveness of different models (NRC 2011). Students created nonfiction books as they learned about different objects in the solar system. Below we describe the distinct, yet related parts of our integrated unit.
Building Models of Mars Landers

During the first week of the science unit, students spent science time learning about Mars and researching the history of spacecraft that landed successfully (or not so successfully) on Mars. During language arts, students read and wrote about Earth and made Venn diagrams comparing the planets. We wanted students to understand why Mars might be an interesting place to explore, but a difficult place to inhabit. Also, to prepare for the upcoming engineering task, they read books about the *Mars Pathfinder* and answered questions about the goals of the mission and the design of the spacecraft. They visited the NASA website to look at video clips of a simulated landing and drew pictures on sticky notes to show the landing sequence (Figure 1). Students enjoyed watching a DVD that showed engineers and scientists discussing design problems and failures (Arizona Public Media 2007).

At the beginning of the second week, students were given the task of designing spacecraft that would be launched (from our gymnasium roof) and land safely on the surface of Mars (our school parking lot) with functioning scientific equipment on board. Students worked in mixed-ability groups to create a plan for their spacecraft (Figure 2). Large maps of Mars were displayed in the classroom, and students selected where they would like their spacecraft to land based on the research questions they hoped to answer when they “landed.” They also selected what type of scientific equipment would be needed to carry out the research. Students included models of equipment such as cameras, drills, weather instruments, solar panels, and even rovers. All of the planning for the landers occurred in the days leading up to construction of the models. After great anticipation,
students began building their models with materials collected from home and school. The goal was to have the spacecraft arrive safely at its destination with all of the model equipment intact.

Watching the young scientists try out ideas and share strategies was a highlight of this unit. Many groups used parachutes (crafted from old sheets or garbage bags) to break the fall, whereas others tried air bags (such as bubble wrap or pillows) to cushion the landing. Students grappled with important engineering concepts as they experimented with parachute size and materials, models of air bags, and shape and weight of the landers. They “piloted” the landing by climbing to the top of the playground slide (supervised by a teacher) and tossing them in the air. Adjustments were made after observing the landing from a short distance. The day before the launch, students presented their models to classmates and described their research questions and equipment. Landers were assessed using a rubric (see NSTA Connection), which evaluated students on aspects of the project such as scientific questions and materials, teamwork, creativity, and durability. After each student presentation, students answered questions about designs from classmates, such as “How will your data be sent back to Earth?” or “Why did you decide to study the temperature at the equator? What do you expect to learn?” They also made predictions about which landers would work best, such as “I predict Cyber Ice is too heavy to land softly and smoothly.” Metacognition was encouraged as they elaborated on the strengths and potential weaknesses of their models. On the day of the launch, parent volunteers transported the landers to the roof of the gym and “launched” them according to team specifications. Volunteers stayed several feet back from the edge of the roof and pitched the landers forward to ensure their own safety. On the ground, students were kept outside of the “landing zone.” There was much enthusiasm on the day of the “launch” and many cheers as models flew through the air to their final destination. Other students helped assess the durability of each lander by “rating” how well it landed after each launch.

Creating Solar System Books

While students were learning about Mars and engineering in science, they were engaged in reading and then writing their own nonfiction books about the Sun, Moon, and Earth during language arts. Students compared the Earth and Moon to Mars throughout the unit. For example, they found that Mars is a little more than half the size of Earth, but twice the size of the Moon. They were surprised to learn there are volcanoes and canyons on Mars that are larger than any found on Earth. Students found answers to scientific questions (Figure 3) by reading and synthesizing knowledge from reliable sources and making connections to prior knowledge. A variety of library books and some trade books at different levels were made available in our classroom for students to refer to as they crafted their answers to the questions (see NSTA Connection).

Each concept was addressed using a combination of read-aloud, direct instruction, hands-on activities, demonstrations, and independent reading. Seymour Simon’s book, Our Solar System (1992), provided background knowledge for many of the topics. Modeling relationships between objects in the solar system played an important role in helping students developing understanding. For example, on the day when students were learning about Moon phases, we read aloud about why and how the Moon has different “phases.” Then, each

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**Figure 3.** Writing prompts for nonfiction, student-designed books.

Each of these prompts was written on a blank page with space for a picture at the top and lines for writing and vocabulary at the bottom.

1. **Why is the Earth so special?**  
   Words to use: atmosphere, nitrogen, oxygen, temperature, water

2. **How does the Earth move?**  
   Words to use: rotate, revolve, orbit, axis

3. **What causes seasons on the Earth?**  
   Words to use: tilt, axis, hemisphere

4. **What is the Moon like?**  
   Words to use: satellite, crater, surface, atmosphere, Apollo

5. **How does the Moon move? Why does it look different each night?**  
   Words to use: rotate, orbit, waxing, waning, new Moon, quarter Moon

6. **What is a solar eclipse?**

7. **What is a lunar eclipse?**

8. **Compare and contrast the surfaces of Earth, our Moon, and Mars. Choose your own scientific vocabulary to show off what you know!**
student modeled the revolution of the Moon around Earth as Earth revolved around the Sun. On the day we studied solar and lunar eclipses, we read about eclipses together. Then, using a lamp in the middle of the dark room to model the Sun, students used Styrofoam balls on the ends of pencils to model the Moon and move these balls around their heads (Earth) to visualize how eclipses occur. Students could see the full Moon disappear behind Earth’s shadow (their heads’ shadows), thus causing a lunar eclipse. Additionally, the new Moon would block the Sun’s rays to parts of their faces, thus causing a solar eclipse. When we studied seasons, we read about how seasons occur, and then students used a globe, tilted on its axis, to maneuver it around the Sun (a lamp) that was in the center of the dark classroom. Students could see how the tilt of the Earth directly affected the amount of sunlight different parts of Earth received as it traveled around its orbit. They also completed a night sky journal to help them connect science concepts with observed events in their daily lives.

Providing guiding questions and key vocabulary seemed to offer the right amount of scaffolding for young students as they grappled with difficult science concepts. Graphic organizers were used to write down important information that students wanted to include in their writing. Students used their writing journals to create a rough draft of their response to the question. The teachers (and parent volunteers or resource teachers) edited their ideas to make sure that the science content was accurate before students made a final draft in their booklets. We encouraged students to highlight the important vocabulary words within their paragraphs to ensure that they included and explained all concepts.

It was challenging, at times, to read and process 20 or more student responses and offer constructive feedback—both about the science and the writing. It was a tricky balance to offer advice and address misconceptions as they came up without taking ownership of the writing from the students. We occasionally delayed responding to student misconceptions when we were unable to get to each student’s responses or when students didn’t finish their response during class time. Sharing time was a chance to promote discussions about scientific ideas.
We purposefully selected accurate examples of writing or illustrations for students to share, making sure to include students who were less confident in science to share when they were on target. Students were encouraged to provide feedback and ask questions after peers shared their thinking and drawings. Students seemed to understand the concepts well when they were given the task of writing and drawing about the important ideas each day. Research suggests that when students represent ideas using their own drawings or diagrams, it strengthens their conceptual understanding (Edens and Potter 2003; Gobert and Clement 1999). Figure 4 (p. 39) provides some examples of student work on selected pages of the books.

Assessments

Students were given open-ended questions in the preassessment to help inform us of their initial conceptions about the “big ideas” of the unit. Research suggests that when teachers elicit student preconceptions and address them during instruction, students are more likely to develop understanding (Donovan and Bransford 2005). We used open-ended assessment questions to elicit student understanding of these concepts and examples of student work. Each year, we modify the questions slightly to clarify them or emphasize different ideas. Using the same questions for the preassessment and summative assessment provides teachers and students with an opportunity to reflect on how ideas changed during the unit. Also, student booklets were assessed using a scoring rubric, which informed us about students’ conceptual understanding of the big ideas with support.

Teaching about the movement of the Sun, Moon, and Earth is challenging, and requires sustained focus on the “big ideas” through a variety of activities and tasks. Making comparisons between Mars and Earth helped students appreciate the unique characteristics of our planet. Although every student didn’t master concepts at the same level during our three-week unit, we found that all students moved forward in their thinking and improved their content knowledge when they used their own writing and drawing to represent their ideas. When students engaged in model building during science class, they felt like engineers as they built and tested their designs. Mars landers are a creative alternative to the more traditional egg drop activity. Watching the students cheer as their lander parachute opens perfectly is similar to watching engineers at NASA exhibit enthusiasm when a spacecraft arrives safely at its destination.

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Connecting to the Standards

This article relates to the following National Science Education Standards (NRC 1996):

Grades K–8

Content Standards

Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry

Standard D: Earth Science
- Objects in the sky

Standard E: Science and Technology
- Abilities of technological design

With the increased focus on both inquiry and 21st-century skills such as collaboration and problem-solving, teachers at all levels are looking for engaging ways to create more student-centered classrooms in which students can learn more than “just” science content. Discovering and developing creative science activities designed to accomplish multiple learning objectives has become part of the must-do list for every teacher. This article shares the successes experienced in integrating the important health concept of tooth decay with data analysis.

Tooth decay offers the perfect opportunity to study chemistry in a context in which students are all-too-familiar. In fifth-grade science, we began our study of chemistry with acids and bases. As part of that unit, students used litmus paper to identify common acids and bases used in everyday substances. From there they used inquiry to tie the pH scale to what they knew about acids and bases, developing their own working definitions of these terms. This was accomplished by comparing their results of the litmus paper tests with the testing of the same liquids using pH paper. Through a series of open-ended investigations, students were able to relate the numbers on the pH scale to acids and bases. Many questions arose about the acidity of the different drinks the students consume on a daily basis. Students chose to test several drinks to determine their level of acidity. Students had just gained specific knowledge about typical beverages that were acidic and wondered about their effect on their teeth. This was a natural lead-in to applying our knowledge of acids and bases to an investigation of tooth decay. Here began our open-ended study of the effects of different liquids on tooth decay.

Maximizing Learning

To maximize meeting multiple goals during an inquiry activity, I typically make a mental list of what students should already know and be able to do and what will be new ideas or tasks for students. By thinking about these two categories during my planning process, I can better ensure learning occurs in a multitude of dimensions. For example, for this project my thought process ran like this:

What students already know and will use in this project . . .

• How to brainstorm ideas as collaborative group members
• How to set up a “fair test”
• How to organize and complete data tables
• How to calculate averages
• The relationship between pH and the level of acidity of various drinks
• How to summarize results of experiments
• How to “whiteboard” their findings as a way of sharing with the class

What will be new to students in this project . . .

• Using electronic balances to mass the teeth
• The meaning of qualitative versus quantitative data
• The idea of insignificant changes due to error
• How to apply their new knowledge about tooth decay to their own eating habits

A multidisciplinary inquiry activity for fifth-grade students

By Jody H. Stone
Some of this information is gleaned through open-ended questions with students at the beginning of the school year, and the rest is based on my knowledge of the content and activities engaged in during science at each grade level.

Setting the Stage

We began by brainstorming a list of liquids that typically come in contact with our teeth (Figure 1). This was followed by a class discussion in which groups of students made predictions about whether each of these liquids would be good for teeth, bad for teeth, or have no effect. As students made their predictions, they were required to provide a scientific reason to justify each of their predictions. A lively discussion ensued in which students applied their knowledge of the acidic nature of pop and of vinegar from the previous unit, along with a smattering of information the students seemed to have from who knows where (some of which was not correct). For example, several students commented that they had heard pop could “eat through” a nail and vinegar can make a bone “rubbery.” One girl reported that her mom said her teeth would rot from eating hard candy. The common strand seemed to be that something in these substances was somehow “bad” for your teeth. Students liked to use the word rot, but after considerable discussion we settled on disintegrate.

Guiding Students With Questions

Our next order of business was to think of what materials we would need to carry out a scientific test to see whether these liquids really caused teeth to disintegrate. Through guided discussion, students developed a list of materials, along with initial ideas for what would constitute a fair test. Because we devote a great deal of time to inquiry-based learning in my science classroom, students have a good idea of what it means to design a fair test. They know a fair test involves controlling variables. By asking questions designed to get students thinking about the details of their experimental setups, the idea of a fair test is constantly reinforced. Some of the questions posed to students throughout this discussion include the following:

“If we were going to carry out a scientific test of our predictions, how might we go about doing that?”
“Let’s make a list of what we would need.”
“How about containers?”
“Is it important that the containers have lids or doesn’t it matter?”
“Do all the containers need to be exactly the same?” (Not really, they just need to have the same amount of liquid in them.)
“What about the liquids? Does it matter how much liquid we put in each container?”
(No, but it is important that all containers have the same amount of liquid in them.)
“How many containers will we need?”
“Do we need to test the same liquid more than one time?”

Making this Inquiry Lab Work for You

If you are interested in carrying out this activity in your elementary classroom, a good source of teeth is important. Dentists are no longer allowed to give teeth away; they must pay a substantial amount of money to dispose of this biological waste. I purchased some cow teeth on the internet. They were huge and beautiful, but as a group of my students discovered, they were varnished and would not degrade in any liquids except vinegar. The results with these teeth were disappointing. An excellent source of teeth is from owl pellets, although these are significantly smaller than cow’s teeth. We had completed an owl pellet unit previously and had saved all of the rodent teeth before discarding the bones. The owl pellets were commercially purchased and had been sanitized, so they were safe for classroom use. Another possible source of teeth is your local veterinarian. We also retrieved teeth from a local farmer who raised beef. These teeth were super for this activity and the source is plentiful and free.

Any teeth secured from these sources should be soaked in bleach for several days by the teacher, then placed in cheesecloth and washed in the dishwasher. This will remove any potentially harmful substances from the teeth. In the event that no safe source of teeth can be located, the activity will work by replacing the teeth with cooked chicken bones, egg shells, or pieces of limestone. However, be aware that this substitution can lead to student misconceptions about teeth and bones being identical and decreases the relevancy of this particular activity.
Students had done enough activities previously in science class that they knew they needed more than one trial and decided that three sets of each test would probably be enough. “How about teeth?” “Where do we get them?” There were many ideas for where to get the teeth, from the local dentist to the students’ “stash” at home. “Do all of the teeth need to be identical?” In an ideal world, yes, but that is unrealistic for this lab. “What information do we need to collect about each tooth?” Students decided they wanted to see whether the teeth were being “eaten up” by the liquids and also wanted to know whether the teeth were being discolored by the liquids.

**Setting Up Experiments**

After much discussion, students formed groups; each group was on its own to decide on the liquids from the list it wanted to test and the exact procedures students would follow. All students must wear indirectly vented chemical-splash goggles when handling the teeth and the liquids. Remind students to never taste or drink food used in a science activity and to always wash hands with soap and water upon completing the activity. Safety pointers related to securing teeth are provided on p. 42.

Groups of three work well, if there are enough teeth for this many students. I supplied the containers and lids, the beverages, the teeth, and electronic balances. For this particular lab, accurate massing is critical. Because I am also the high school chemistry teacher, I had ready access to five electronic balances, which were accurate to 0.01 and 0.001 grams. Massing the teeth with manual pan balances will not yield accurate enough data for this lab and will be very time-consuming. Think about borrowing these devices from your high school for a day or two at the beginning and end of this unit. You could even ask the high school chemistry students to “buddy up” with your elementary students for the beginning and ending “mass in.”

**Accessing Student Ideas**

Students initially left their teeth soaking over spring break, which ended up being a 12-day soak. They rinsed off the teeth and placed them on trays to air dry for several days. One of the students had cleverly pointed out that if there was still moisture in some of the cracks,
the teeth would have more mass than they should have, and it would throw off the results. With all masses recorded, the students decided they wanted to place the teeth back in the liquids for a longer period of time. This ended up being an additional 28 days, resulting in 40 total days of soaking. The teeth were again dried and all masses were recorded. A sample of student data is shown in Figure 2. Students also photographed the teeth both before and after soaking by placing them on white Styrofoam trays to determine whether there was any change in color (Figure 3).

### Introducing Data Analysis

The analysis process revealed which students were proficient with data analysis and which needed additional instruction. Students had previously calculated averages, so this was an application of a previously learned skill. As is the case with most learning, some students were proficient with this task, whereas others were in need of guidance. One of our data analysis “rules” was that two to three different people always do the calculations separately and then compare their answers. This provided many opportunities for students to manipulate real data that had meaning. Those students who initially needed guidance in calculating their averages were confident in this skill by the end of this activity. Many additional learning opportunities presented themselves in terms of data analysis. In addition to the mathematical concept of an average mass gain or loss, students were introduced to the idea of significant figures. Although this is a concept that can get tricky for an elementary student, it is easily handled at a developmentally appropriate level. Through discussion, students decided that if you were using the scale that recorded two decimal places (i.e., 0.39 g), it would not make sense to record more digits than this, even if the average were 0.3896453 g. Students developed rules for rounding and writing averages that matched the number of digits of the scale they used. This was a new idea for students, but it made sense to them. Cementing their skills at rounding was an unanticipated benefit of this data-heavy activity.

### Embracing Challenges

One of the biggest challenges of an activity that is heavily data-based is deciding how much of a change is meaningful and how much is just due to differences in the scale or insignificant inaccuracies. When students were asked, “Which substances tested lost mass?” most students listed the Mt. Dew and Pepsi among their list. The teeth in these two liquids lost 0.07 g and 0.06 g respectively. Through a sequence of questioning, students were able to look at their data and decide in

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**Figure 3.**

Student photo of their experimental teeth.

**Figure 4.**

Science notebook entry.

Conclusions:

1. Which three liquids had the most effect on disintegrating the teeth? Use the average numbers as part of your answer. Write complete sentences.
2. Which three liquids had the most effect on discoloring the teeth? Go back and look at the teeth on the trays to answer this. Write complete sentences.
3. Which three liquids had the least effect on disintegrating the teeth? In other words, which are best for your teeth? Use the average numbers as part of your answer. Write complete sentences.
4. Write a three-paragraph paper about the teeth experiment.
   - **Paragraph 1:** Write about how the experiment was set up including how long the teeth were soaked and how you set up the experiment to have a fair test. Be sure to explain why it was important to have more than one trial for each liquid.
   - **Paragraph 2:** Write one paragraph about the bad effects of the liquids on teeth.
   - **Paragraph 3:** Write one paragraph about the best liquids to drink in terms of not hurting your teeth.
5. Create an advertisement about which liquids are healthiest for your teeth and which are definitely bad for your teeth. Make it appealing to students your age. Include some scientific information on your ad, as well as graphics or illustrations. The ads will be posted around school.
which cases the liquids were actually changing the teeth and in which instances the differences were so small that they did not really matter. A discussion followed in which we talked about how to determine which differences were insignificant. For example, they decided that the importance of differences was really related to the total mass of the teeth. For example, a difference of 0.1 g on tooth samples with masses of 10 to 12 g would not make much difference, but if the tooth samples had a mass of only 0.5 g, this would be a huge difference. Given that these are fifth graders, I felt that this was a big idea. The bottom line was that when given sample data, students were able to use logic to distinguish when small and large differences in mass seemed to make a difference. This was perhaps the most challenging aspect of this activity in terms of data analysis, and I would say that some students were simply not ready for this, as evidenced by their responses on a final assessment. Despite the difficulty in grasping the idea of insignificant change, I believe this was still an appropriate concept for upper elementary students to begin thinking about. Revisiting this concept later on in the year will bring students closer to understanding this important idea.

Assessing Student Learning

In terms of assessing students on their Tooth Decay unit, assessment was accomplished in the form of journal entries in their log books. Figure 4 shows the questions presented to students. These questions were designed to provide information on the depth of student understanding while presenting students an opportunity to use literacy skills to communicate their knowledge with the general public. These literacy skills included communicating both through writing and speaking. Several students chose to present their findings using the free online tool called Glogster (Figure 5). Glogster allows students to create posters with text, photos, videos, graphics, sounds, drawings, data attachments, and more. The student-created poster in Figure 5 contains an embedded video clip in which students explain their experimental design and findings and offers another option in which students can learn new technology while enhancing their writing and communication skills.

If you begin to think of teaching as creating opportunities for students to make some of their own decisions while teaching significant content and incorporating important 21st-century skills, you will quickly become adept at asking more than telling. Your classroom will become a more exciting place in which students can grow in their confidence as decision makers.

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Connecting to the Standards

This article relates to the following National Science Education Standards (NRC 1996):

Content Standards
Grades 5–8
Standard A: Science as Inquiry
• Abilities necessary to do scientific inquiry
Standard B: Physical Science
• Properties and changes of properties in matter
Standard F: Science in Personal and Social Perspectives
• Personal health

How do scientists use science notebooks? How will I use one? These are questions students might have when introduced to a science notebook. Many times students are given the task of keeping a science notebook, but do not fully understand the process or purpose of this endeavor. Science notebooks contain not only data but also questions, predictions, observations, and reflections from their experiences in science.

Effective science teaching involves students making observations and using these observations along with past experiences to create their own personal knowledge. Communication of this personal knowledge is crucial. Students communicate this knowledge verbally with their peers and teachers, but writing these ideas is the next step in solidifying their understanding of science content. The benefits of writing in science are obvious, but what about younger students who are new to the process of writing? Or ELL students who have language barriers that make writing difficult? To maximize the effectiveness of the science notebook, teachers must provide scaffolding for students as they learn to write in a science notebook, just as they would for any form of writing.

Is a Mealworm Really a Worm?

Introducing science notebooks to novice writers through the IMSCI model

By Kimberly Lott and Sylvia Read

Safety Considerations With Mealworms

- For more information on the care of mealworms, visit: www.sialis.org/raisingmealworms.htm
- Each group should have their own container of mealworms that they observe each week. Small, disposable plastic containers work great for this. Just make sure there is adequate bedding (oatmeal) and air holes for ventilation. We numbered the containers to correlate with the student group number to ensure that each group observed the same mealworms each week.
- For weekly observations, we encouraged our students to put the contents of their containers on foam trays and use spoons to move the contents (mealworms, skins, pupa) around.
- If students do touch the mealworms, they need to wash their hands after observations.
- Treat live or preserved animals or animal parts with care to avoid harming the animals or yourself.
The IMSCI model for scaffolding writing in language arts can also be used with a science notebook (Read 2010). IMSCI includes Inquiry, Modeling, Sharing, Collaborative, and Independent phases. To illustrate how the IMSCI model can be used in an early elementary classroom, we’ll describe a six-week unit on insect life cycles completed with first graders at the beginning of the school year.

**Background**

The concept of life cycles is taught in most early elementary classrooms. Students have often heard stories of caterpillars turning to butterflies or tadpoles to frogs; however, many students have never closely observed a mealworm and have no idea that they are even insects. For this reason, we chose to study mealworms for our unit because this would be an opportunity for students to use their inquiry skills to create new knowledge about the life cycle of an unknown organism.

To document their inquiry experiences, students would be using science notebooks. Many of the children in this first-grade class had writing difficulties, so writing independently in a science notebook would have been a daunting task without the scaffolding provided through the IMSCI model. We created a class notebook for modeling and shared writing, had students work with a group notebook for collaborative writing, and encouraged them to write independently in their own notebooks.

**“I” is for Inquiry**

When introducing a class to science notebooks, lead the students in an inquiry activity, the first phase of the IMSCI model. Before we began our unit on insect life cycles, we asked the question “What is a science notebook?” Many students answered, “I don’t know” another answered, “a notebook you write stuff in about science.”

We then started our inquiry into science notebooks. We explained that scientists use science notebooks to record information about the natural world. We read the children’s book about a famous scientist Neo Leo: The Ageless Ideas of Leonardo Da Vinci by Gene Barretta (2009). Leonardo Da Vinci was not only an artist, but also an inventor, engineer, and scientist who made thousands of notes and drawings that would become modern day inventions like airplanes, automobiles, contact lenses, and many more. The book beautifully illustrates the drawings taken from Da Vinci’s notebook alongside the modern-day invention the drawing inspired.

We have also found that sharing examples of science notebooks written by children is appropriate. We downloaded sample pages from student notebooks at *Science Notebooks in K–12 Classrooms* (see Internet Resource).

We showed several examples of science notebook pages written by students at the same grade level, bringing to students’ attention the different types of entries and organizational elements found in science notebooks. We also read the fictional story A Crack in the Night by Marcy Skinner with Kimberly Lott and Max Longhurst (2010). This story is about a boy using a science notebook to discover what goes “crack in the night.” The boy is a regular kid using a notebook for scientific study, reinforcing the idea that you do not have to be a scientist in a lab to use a notebook.

**“M” is for Modeling**

The next stage is to model for the students the entire process of writing a notebook entry—not only the writing parts of the entry, but also the “think-alouds” that occur before and during the writing process. Through modeling, teachers can explicitly show the role this internal dialogue can play in the final written product.

Modeling was implemented with the first graders in their first drawings of the mealworms. On the first day of the unit, students observed mealworms. We did not tell them that we were completing a life cycle unit because we did not want the students to know that the mealworms were going to change. Working in cooperative learning groups, the students were given several mealworms on a paper plate. Students were told that these organisms are called mealworms and were asked to make observations of this new organism. With a hand lens, the students examined the external features of their mealworms. We then had students draw a picture of a mealworm in their individual notebooks. From those initial drawings, we found that drawing “scientifically” was a new skill for these first graders. We took out a flipchart
and modeled for the students how to draw and label a picture of a mealworm in the “class notebook.” We spoke aloud (e.g., “It looks like a worm, but it has a hard shell” “The shell looks like it has parts, so I need to make sure I draw that” and “It is moving with what looks like legs, but the legs are not on the entire body, just in the front.”) and then made a large drawing of a segmented body and labeled the legs in the class notebook. After modeling, the students made another drawing of a mealworm in their science notebook beneath their original drawing (Figure 1). As you see from Figure 1, the initial drawing was small and with few accurate details. After modeling, the student drew the picture larger with more details and included labeling. In some cases, students added their own labels in addition to the ones listed in the class notebook drawing (e.g., a student added “tal” to his diagram to indicate the tail of his mealworm, which was not in the modeled drawing.)

“S” is for Sharing

Shared writing is when the teacher is the scribe for the students as they compose aloud. Shared writing can also be combined with modeling when the teacher starts out writing a notebook entry, but the students help finish composing the entry.

During the second week of the unit, the students observed their mealworms again and wrote a shared entry in the class notebook. To guide their inquiry, we wanted them to focus on specific questions when observing their mealworms. We started out by writing two questions on the class notebook flipchart:

• “Is a mealworm really a worm?”
• “How does a mealworm move?”

We asked the students to think of other questions that they wanted to know about mealworms. The student questions—“What do mealworms eat?” “Can they see?”—were then added to the class notebook.

Working in cooperative groups, the students observed their mealworms again looking for evidence that could be used to answer the questions in the class notebook. They used plastic spoons to move the mealworms around the plate to watch their movements. They also used the spoons to see whether the mealworm could “see” it if it were placed in its path. They used hand lenses to look for “eyeballs.” After their observations, we answered the questions through a whole-group discussion and recorded student responses in the class notebook (Figure 2).

“C” is for Collaborative

Collaborative writing occurs when students write in pairs or groups on one notebook entry. Collaborative writing entries can also be between teacher and student, but the most feasible method for most elementary classrooms is collaboration between students. This form of writing is especially effective in a diverse student classroom to help meet the learning needs of all students. For
example, more advanced student writers can be paired with less skilled writers. Also, ELL students can work with other students, which will provide support in the form of comprehensible input and meaningful repetition (Neuman and Koskinen 1992).

Students made weekly observations of their mealworms over the next four weeks and documented their findings in a “group notebook.” Students were asked to observe and document any changes that they observed in their mealworms or mealworm containers. The students would spend several minutes observing their mealworms on a paper plate and talking aloud about any changes that they observed. After the observations, the group would make a collaborative entry in the group notebook. Students worked together in groups of four with each one being a scribe for one of the weeks. These entries varied by the skill level of the scribe, with more skilled writers using more written language (Figure 3a), and less skilled writers using more numbers and pictures in their entries (Figure 3b). A checklist was used to monitor student progression during these four weeks of collaborative entries (Figure 4, p. 50).

Students observed a variety of changes during the four-week observation period including changes in mealworm color (some lighter or darker than previously observed); changes in mealworm size; changes from mealworm “shells” at molting stage to pupa stage; changes from pupa stage “shells” to beetles; and changes in beetle coloring (from lighter to darker). We let students use whatever vocabulary they wanted to describe their mealworms. In some cases, students already knew terms like molting when they observed skins of their mealworms. Other times, they used terms like thingy to describe the pupa stage of the life cycle. A word wall with content-specific terminology generated during these hands-on observations can be helpful when students are composing notebook entries.

“1” is for Independent

This is the phase in which students write their own entries in their science notebooks. Because the students have participated in inquiry, modeling, and shared and collaborative writing, they will be more successful when writing entries independently.

During the final week of mealworm observation, it was time to put together the life-cycle of the mealworm. We read Monarch Butterfly by Gail Gibbons (1991). We modeled for them how to draw a life cycle of a butterfly (egg, caterpillar, pupa, and butterfly) in the class notebook. Using the evidence they had collected in their group notebooks the previous weeks, the students then independently drew the life cycle of the mealworm including egg, mealworm, pupa, and beetle in their own science notebooks. We noticed that the more skilled writers put only words in their cycles (Figure 5a, p. 51) and the less skilled writers used invented spelling and pictures in their cycles (Figure 5b, p. 51). We went on to explain the more scientific terms...
for the mealworm (larva) and the beetle (adult) stages of life. The scoring rubric for the final independent entry can be found online (see NSTA Connection). We ended the unit by asking one of the initial questions, “Are mealworms really worms?” The boy in the class who was the most insistent at the beginning of the unit that they were worms because they were “squirmy” answered, “No. They are really beetles!”

**Final Thoughts**

This unit was completed at the beginning of the year with children who had little experience with science notebooks; therefore, it was the perfect unit in which to illustrate every step of the IMSCI model. However, the IMSCI model can be adjusted depending on the levels of your students. With older students, teachers can start with an inquiry and then decide, based on the students’ abilities, the next step in the scaffolding process. More skilled writers may need little modeling and sharing, so a class notebook may not be necessary. A group notebook for collaborative writing might be a more appropriate starting point.

Science notebooks are students’ personal records of their learnings about the world around them and also provide teachers an effective method for assessing and giving feedback (Ruiz-Primo, Li, and Shavelson 2002). When students are just beginning to use science notebooks, scaffolding in the form of modeling, shared writing, and collaborative writing will provide the needed support as they learn the features that can be included in a notebook.

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### Figure 4.

**Checklist for collaborative entries.**

<table>
<thead>
<tr>
<th>Week</th>
<th>Basic</th>
<th>Proficient</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Data entered in a random pattern, not organized. Only records ideas when prompted. Ideas recorded may be both accurate and fictional.</td>
<td>Data is more organized (i.e., titles, groupings). Drawings present with labels. Sentences added to describe thinking. Less prompting from the teacher. Ideas recorded are accurate.</td>
<td>Data is organized in a thoughtful manner that can be justified by the student (not just instructed by teacher). Method of recording data takes on many different forms including drawings, sentences, charts, and tables.</td>
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<td>6</td>
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</tbody>
</table>
entry. If teachers do not scaffold students as they learn to write in their science notebooks, students may become confused, not because they misunderstand the science concepts, but because they may be uncertain about how to write in a science notebook. For this reason, the written entries in a science notebook may not accurately reflect the students’ actual scientific knowledge. To assess what students have learned in their science notebooks, they have to adequately communicate this knowledge through their writing and visual representations. By using the IMSCI model, teachers can be more confident in their assessment of science content in science notebooks because they know that the students have had adequate scaffolding during the writing process.

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References

Internet Resource
Science Notebooks in K–12 Classrooms
www.sciencenotebooks.org

NSTA Connection
For a rubric, visit www.nsta.org/SC1201.

Connecting to the Standards
This article relates to the following National Science Education Standards (NRC 1996):

Content Standards
Standard A: Science as Inquiry
  • Abilities necessary to do scientific inquiry
Standard C: Life Science
  • Characteristics of organisms
  • Life cycles of organisms

The coffee is flowing as 30 teachers meet on a Saturday morning. After greetings and updates, the teachers focus on science content and teaching strategies. It’s a long day, after a long week of teaching, but energy and enthusiasm levels are high. During a year together, the teachers have become trusted colleagues, learning partners, and friends.

For the past five years, teachers from four Houston-area school districts have joined together in a professional learning community (PLC) to improve their science teaching. Through the University of Houston–Clear Lake (UHCL) Regional Collaborative for Excellence in Science and Mathematics Teaching, the teachers strengthen content knowledge and share teaching strategies that they then bring back to their home schools as science teacher mentors. Results for the teachers include increased knowledge on science topics (as measured in pre- and posttests), as well as gains in self-confidence, motivation, and leadership skills. Results for students include involvement in more hands-on and lab-based science to prepare them for middle and high school, as well as improved Texas Assessment of Knowledge and Skills (TAKS) science scores. In this article, we (the collaborative project director and a former collaborative teacher who is now an instructional team member) describe how the collaborative works, including its use of the environmental education program Project Learning Tree (PLT) as a thread that connects the collaborative members. We also suggest ideas for teachers who are interested in creating or joining a professional learning community.

How Teachers Get Involved

Our collaborative is a PLC for classroom science teachers of grades 3–12. PLCs are frequently designed and implemented in a single school district to create a positive effect on students (DuFour 2004). But this collaborative is slightly different, because it brings together teachers from a variety of schools and school districts. It connects science teachers who may otherwise not meet, much less form a collaborative network.

Each year, 25 to 30 participants are selected from four independent school districts (ISDs): two Title I, urban districts (Houston and Pasadena) and two suburban districts with a diverse range of schools (Clear Creek and Pearland). Teachers with at least three years of experience (not necessarily in science) submit an application and three letters of recommendation to join. By now, most come via word of mouth from previous participants or district science coordinators and principals. Each year, 5 to 10 members are returning teachers; the combination of “newbies” and veterans works well.

If accepted, participants become science teacher mentors, underscoring that they join not only to strengthen their own knowledge but also to mentor others. They fulfill 105 hours of professional development over the course of the school year through:

- Monthly, mandatory three-hour workshops.
- Courses on the year’s specific topics.
- Other workshops/summer institutes addressing individual needs in science or pedagogical content.

In addition, teachers follow individual professional development plans. First, they form a strong learning network across school districts. This builds the collaborative culture and provides an opportunity for teachers to share common visions. Second, multiple workshops focus on science concepts and pedagogy—strengthening their content and connection to the nature of science. In addition to events that all teachers attend, we work with each member to tailor a yearlong program to meet his or her individual and school’s needs. Finally, the PLC provides opportunities to present, mentor, and lead—with other PLC members and back in their home schools and communities.
As one member said, “Participation in the collaborative has completely changed my teaching. It has helped me develop the content knowledge required to be a successful elementary science teacher….This, in turn, has improved my students’ understanding of the concepts as evidenced not only by their improved TAKS scores, but by their continued success in their science classes once they leave fifth grade.”

**Strategies That Work**

Over the years, we have found two threads that bring the most value to the PLC and best connect and energize the group: (1) the monthly three-hour workshops and (2) the use of environmental education, especially PLT, to thread together different science topics.

We do not have weekly meetings with the cohort group because they come from across the greater Houston area for the PLC. Instead, we have monthly meetings at which we conduct workshops focusing on environmental education, science content, or pedagogy. We also build time into the workshop for individuals to share what is working in their classrooms and address challenges the teachers may be experiencing. In the end, the monthly meetings provide an opportunity for the collaborative members to build and strengthen their PLC. We frequently offer workshops every week, in some form or fashion, focusing on both content and pedagogy in the areas of science and environmental education. Some of the collaborative science teacher mentors attend, but not all do, unless it is a required workshop for all. So, there will be a variety of teachers at these workshops—science teacher mentors and cadre members (both preservice and inservice educators).

PLT, a national preK–12 environmental education program that began in 1976, offers hands-on, interdisciplinary curricula correlated to Texas’ (and most states’) science standards, as well as other subject standards (see Internet Resources for more information). PLT workshops are a good fit for us, because they are practical, easy-to-implement, and can cover the different topics we need to address. In addition to preK–8 and secondary activity guides that cover a broad array of topics, PLT offers an *Energy and Society* curriculum that several Texas ISDs have incorporated into their fifth-grade science curriculum. Thus, our collaborative frequently draws on *Energy and Society* to share strategies on teaching potential and kinetic energy.

**A Science Focus**

The National Science Education Standards recognize the value of teachers learning and sharing within PLCs. Teachers gain solid science content, share teaching strategies, build presentation skills, and develop a network of colleagues to whom they can turn (NRC 1996). Research (e.g., Sack and Kamau 2006; Quint et al. 2007) shows the positive effect of PLCs on teachers and students.

Our mission is to “create a science and technology learning community for the Greater Houston area teachers, schools, and districts through program development and sustained teacher professional development in science content, pedagogy, systemic school reform, and technology.” Now in its fifth year, the collaborative is, itself, a collaboration: a partnership of the School of Education, and School of Science, Computers and Engineering at the UHCL; the Environmental Institute of Houston; local school districts; and nonformal providers. It is also a member of and receives funding from the Texas Regional Collaborative for the Excellence in Science and Mathematics Teaching (TRC). Each year, the TRC encourages regional collaboratives to focus on topics based on state test results as well as to select topics based on local issues. Our partners have identified energy and environmental issues as additional priorities, given our location on the Gulf Coast and in an urban area.

**The Results**

Collaborative teachers tell us they come to consider each other “family.” With trust established, they share information and strategies from a workshop’s opening minutes to the very end and beyond. For example, prior to state testing, teachers share practices, strategies, and resources to improve student outcomes. Since the Houston area has a diverse population, they also address multicultural differences and differentiated instruction; one teacher, for example, recently shared ideas on making science accessible to English learners, which resulted in a thoughtful discussion and exchange of ideas. They call and e-mail each other with questions or ideas between sessions and a group of participants established a Facebook page.

Pre- and posttests assess the workshops’ effect on teachers’ knowledge. For example, in the 2008/2009 school year, for one PLT workshop, the overall average score on the pretest was 88%; on the posttest, 94%. For an *Energy and Society* workshop, the overall average score on the pretest was 14%; on the posttest, 71%.

The collaborative also helps teachers develop skills to advance their careers in education, such as presentation skills, building partnerships, observation of a mentee to provide feedback, funding to support science education, and opportunities to gain additional science content. Time is also spent on how teachers can assess students’ progress as they teach a concept. Many take on leadership roles for the first time. For example, one of our most active presenters began slowly, leading an activity or two from *Energy and Society*. She never had the opportunity to present; now she is blossoming and sharing her knowledge with others. Another told us, “Thanks to the
program, I was trusted enough to take over when our previous lead teacher left... and I’m doing my own labs as well (with confidence), using PLT as one of my tools for teaching science.”

One of the collaborative’s most valuable aspects is that members create smaller PLCs back in their schools. One teacher commented, “Sharing information with my peers improves my effectiveness because it forces me to slow down and really consider the usefulness of the lessons I am teaching. I have to put a lot of thought into what lessons I do, how successful they are, and what my motivation is for using them. I also have to make sure that I am confident in the concepts that I am sharing with my peers so that I am prepared for their questions.” Thus, the participants examine why they use a lesson, its effect on the students, and their own teaching strategies, an example of the self-reflection characteristic of a PLC.

Another teacher formed a PLC at her school to improve low science scores. After she and four other teachers attended PLT workshops, they discussed how each grade could use the activities and materials covered. The principal scheduled a professional development day during which the PLT-trained teachers held a workshop for the rest of the faculty. More teachers began to base their science classes on environmental education, using the outdoors as a teaching tool. The school’s TAKS scores rose from a 19% to 54% passing rate in one year. In another Houston ISD school, when teachers focused on applying what they had learned from the collaborative throughout their school, fifth-grade TAKS scores rose from 67% passing in 2008 to 100% in 2009 (self-reported scores based on questionnaires because we cannot access individual TAKS scores).

Success goes beyond test scores. As another teacher pointed out, “The effectiveness of the collaborative cannot be measured with just one campus’ scores, as I believe our participation has benefited the entire district. Through the collaborative’s networking, our teachers have received expanded opportunities for participation in workshops, grants, etc. The professional development activities have been shared among our peers throughout the district.”

Many collaborative members also mentor preservice teachers placed in their schools. Although the college students may be exposed to PLT and other hands-on activities in science methods classes, their field placements let them do or observe their mentor teachers using these techniques. Indirectly, the collaborative is benefiting a new generation of teachers.

The Importance of Support
Support from school principals, science coordinators, and UHCL leadership strengthens the collaborative. To gain this support, we must demonstrate the benefits. Many science specialists/coordinators accepted our standing invitation to attend workshops alongside their teachers. Even if they attend only one or a few, they understand what we do and what is required of the collaborative teachers. This also helps extend the development of PLCs within the school districts.

Principals and science coordinators who have seen the effect of the collaborative are often our strongest recruiters. At one school, thanks in part to the principal, three-quarters of the science teachers have joined the collaborative over the past five years and three have become PLT-trained facilitators, a majority of the science teachers have attended Energy and Society workshops, and the entire staff has been trained in PLT’s preK-8 Activity Guide.

We celebrate our successes by hosting an annual “Honoring the Teacher” event, recognizing teachers who participated during the previous year. Principals, science coordinators, UHCL administrators, and community leaders attend. The event serves a dual purpose: the teachers appreciate the involvement of these decision-makers, and the administrators see what each year’s cohort has accomplished.
Making the Most of a PLC

A first step in enhancing professional development is to identify one’s own gaps in specific content or pedagogy, then look for opportunities to fill those gaps through nature centers, zoos, museums, universities, regional service centers, and state agencies, as well as online communities such as the NSTA Learning Center. Doing so might uncover an existing PLC to join.

If you are interested in forming a PLC, talk to other teachers at workshops that interest you. Once you find like-minded teachers, you can form a PLC or at least begin attending workshops and other events together. Whether at an individual school, in one grade level, or a regional cohort, our experiences have provided us with suggestions for science teachers who want to join or form a PLC:

- Explain expectations up front: Teachers need to know the time commitment.
- Combine content and pedagogy: Although some workshops focus on content and others on pedagogical issues, the reality is the two areas intermingle. For example, as teachers learn how to teach energy content to English language learners, they increase their own knowledge and share strategies on relevant assessments.
- Think broadly: A PLC is more than workshops and other professional development. It encompasses such characteristics as a shared visitation, collaborative culture, self-reflection, and shared leadership.
- Consider environmental education as a unifying concept: We have found that environmental education curricula captures the interest of teachers and students alike and is a strong thread that connects our PLC teachers across school districts and from year to year.
- Foster ongoing interaction: We all benefit from sharing what worked and what didn’t work as well as we would have hoped.
- Celebrate success: Have a formal event (e.g., “Honoring the Teacher” event), nominate members for awards, and recognize those who receive awards.

A PLC like the UHCL collaborative provides a support system in which teachers grow professionally and form networks that benefit themselves, their school districts, and their students. We hope to remain a part of and nurture this PLC for many years to come.

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References

Internet Resources
Project Learning Tree  
www.plt.org
Texas Regional Collaboratives for Excellence in Science and Mathematics Teaching  
www.thetrc.org
University of Houston-Clear Lake/EIH Regional Collaborative  
www.uhcl.edu/portal/page/portal/EIH/education/collaborative

Connecting to the Standards
This article relates to the following National Science Education Standards (NRC 1996):

Professional Development Standards

Standard A:
Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry.

Standard B:
Professional development for teachers of science requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching.

Standard C:
Professional development for teachers of science requires building understanding and ability for lifelong learning.

Standard D:
Professional development programs for teachers of science must be coherent and integrated.

Standard F:
Schools must work as communities that encourage, support, and sustain teachers as they implement an effective science program.

NASA and NSTA teaching resources can accentuate your Earth and space science lessons.

By Toni Ivey, Julie Angle, Albert Byers, Steve Marks, and Paul Tingler

Few things excite science educators more than NASA and NSTA. Teachers recognize these two entities for their expertise in Earth and space science and science education, respectively. We jumped at the opportunity when these two superpowers asked us to develop online short courses for science teachers that combined their resources! Through the NASA IDEA (Integrating NASA Digital Educational Assets) project, we developed a series of short courses that combined the NSTA Learning Center resources with NASA's educational websites. Teachers can access the NSTA online short courses through the NSTA Learning Center's learning resources and opportunities section (see Internet Resources). These short courses cover a variety of science content areas and teachers can elect to receive graduate credit through Oklahoma State University. We developed one of these short courses around the NSTA Sci-Pack: Earth, Sun, and Moon (see Internet Resources). To develop the course, we sought out NASA digital resources that would complement it. In this article, we share some of our favorite digital resources for grades K–6 from both NASA and NSTA to teach concepts about the Earth, Sun, and Moon.

The study of Earth and space sciences is complex in that its content is interdisciplinary in nature. Many modern branches of sciences (i.e., chemistry, physics) began in part as a study of physical sciences (i.e., forces, energy, gravity, magnetism). The new document, A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC 2011), presents a new organization of Earth and space science content around three core ideas that are current, accurate, and relevant: (1) Earth’s Place in the Universe, (2) Earth’s Systems, and (3) Earth and Human Activity.

Available NSTA Resources

Before we explore these great resources, we would first like to explain the selection of resources you have at your fingertips in the NSTA Learning Center, an e-professional development (e-PD) portal designed to help teachers tailor professional learning experiences to their pedagogical and content needs (see Internet Resources). The Learning Center provides teachers with access to journal articles, book chapters, web seminars, interactive modules, and online courses. Here we focus on two resources from the Learning Center: SciPacks and Science Objects.
SciPacks
We developed this short course around the Earth, Sun, and Moon SciPack, which is one of 23 SciPacks currently available in the Learning Center. SciPacks help teachers deepen their understanding of content as they proceed through interactive modules called Science Objects (more on these later) and incorporate an inquiry-based approach to learning. They take about 10 hours to complete. Teachers can even contact content mentors via e-mail if they have questions about the content in the modules. There is a pedagogical component in each SciPack that will help teachers translate the material to their classroom. Further, teachers who pass the final assessment can print a certificate that some schools will honor for continuing education credits. The Earth, Sun, and Moon SciPack focuses mainly on the position and motion of the Earth, Sun, and Moon and on the phenomena that can be explained by their position and motion.

Science Objects
The NSTA Learning Center currently has 87 Science Objects. All are inquiry-based, interactive content modules that are free (yes…we said free!). The Earth, Sun, and Moon SciPack is composed of four Science Objects: Earth Characteristics, Our Moving Earth, Motion of the Moon, and Earth’s Seasons. These two-hour modules are great for teachers needing a content refresher or for those that may be teaching a subject for the first time. Each module engages teachers through interactive simulations and evaluates your comprehension through embedded assessments. Additionally, they provide many real-world examples so that you can better explore and explain the content in your classroom. Moreover, they help teachers improve their practice as they help increase content knowledge and address many student misconceptions.

How to Identify Good Inquiry Lessons
How teachers deliver science content to their students is equally as important as teachers’ understanding of the content. During the Earth, Sun, and Moon online course we introduced the Rubric for Evaluating Essential Features of Classroom Inquiry in Instructional Materials document written by the Council of State Science Supervisors (CSSS: see Internet Resources). The CSSS accepts a twofold definition of inquiry as expressed by the National Science Education Standards. First, the CSSS rubric accepts that “inquiry is the process scientists use to build an understanding of the natural world [and] that students can learn about the world through inquiry.” Second, the CSSS rubric is founded on the belief that “student inquiry is a multifaceted activity.” During the online course, we used the CSSS rubric to assist our teachers with evaluating the characteristics of all education learning materials regardless of their source or format. We also used the rubric as a way to measure the level of inquiry in the resources shared below.

Products From the Short Course
As we prepared the online course, we were tasked with identifying creative content, accurate articles, and online websites that complemented each of the Science Objects within the Earth, Sun, and Moon SciPack. Articles from Science & Children are listed in Figure 1 by their corresponding Science Object. These articles provide teacher background information and classroom lesson ideas that complement the teaching and learning about the Earth, Sun, and Moon. Additionally, Figure 1 provides an abbreviated list of the types of student activities found in each article’s lesson (e.g., student research, data collection) or whether it is solely intended to enhance teacher content knowledge.

Some of the NASA-sponsored sites that contain classroom resources, such as science content, lesson plans, pictures, games, and activities, are provided online. Some of these NASA resources focus purely on content and could be excellent resources for teachers needing more information on a specific topic or for students conducting research. Online, we have provided the title and URL of the website, the suggested audience, a description of the website (see NSTA Connection), and the types of resources that teachers can expect to find (e.g., student research ideas, science content information, data collection opportunities, videos). Also, some resources are more inquiry-based than others. Therefore, we recommend using the CSSS rubric, or a similar rubric of your choice, to identify the level of inquiry each lesson offers so you can adjust the resource to fit the needs and skill levels of your students.

Your Space Travel Itinerary
You can enhance your students’ learning experiences by incorporating these journal articles and web resources into your classroom. Sometimes the search for these types of resources can be overwhelming and time-consuming. We have tried to make the preparation for your lessons a little easier by providing you with resources that we believe will increase your students’ interest in Earth and space science in general and the relationship between the Sun, Moon, and Earth in particular. As a reader of Science & Children, you are already aware of some of the great NSTA resources. We hope that this list of resources will help you to incorporate NASA into your classroom as well. After all, NASA and astronauts are what come to mind, for many teachers and students, as the authorities in all things space related. By incorporating NASA activities in your classroom, you know that you will have good content straight from the source. Also, you may just help to inspire the next generation of space scientists!
### Science Object-related *Science and Children* articles.

<table>
<thead>
<tr>
<th>Article Title, Date, and Grade Level</th>
<th>Article Abstract</th>
<th>Type of Activity</th>
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<tbody>
<tr>
<td><strong>Science Object: Characteristics of the Earth</strong></td>
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<tr>
<td><em>Cruising the Climate With Spreadsheets</em> &lt;br&gt;April/May 2010 &lt;br&gt; Grades 4–6</td>
<td>Students collect and record weather data to identify patterns in local weather. Students collect information about weather in other locales from internet weather databases, create spreadsheets, and interpret patterns from student-created graphs.</td>
<td>Data Collection &lt;br&gt;Data Analysis &lt;br&gt;Technology</td>
</tr>
<tr>
<td><em>Layer-Cake Earth</em> &lt;br&gt;December 2006 &lt;br&gt;Grades 4–6</td>
<td>The layers of sediments tell much about Earth’s history. While heading out to dig sites with students is not always realistic, there is a safe, fun, effective way to introduce geology concepts to elementary school children of all ages: “coring” layer cakes! This article describes an exploration of stratigraphy and paleontology with upper-elementary students as they test their observation and measurement skills, collect data, and practice deductive reasoning while investigating a layer-cake Earth.</td>
<td>Student Investigation &lt;br&gt;Modeling</td>
</tr>
<tr>
<td><strong>Science Object: Our Moving Earth</strong></td>
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<tr>
<td><em>Teaching Through Trade Books: Sunrise, Sunset</em> &lt;br&gt;April/May 2009 &lt;br&gt;Grades K–6</td>
<td>This column addresses two levels of student learning. In a lower elementary lesson, students observe the pattern that the Sun follows as it appears to move across the sky. In an upper elementary lesson, students model day and night and explore the need for different time zones on Earth.</td>
<td>Trade Books &lt;br&gt;Patterns &lt;br&gt;Modeling</td>
</tr>
<tr>
<td><em>A Solar Energy Cycle</em> &lt;br&gt;March 2007 &lt;br&gt;Grade 6</td>
<td>In sixth grade, students understand that Earth gets visible light from the Sun, but students may also believe that Earth gets heat from the Sun. This last part is incorrect because the Sun is too far from the Earth to heat it directly. So, how does the Sun heat the Earth? When light strikes an object, it can be reflected or absorbed. Absorbed light usually increases the energy in an object, which causes the object to heat up. This solar energy learning cycle lesson facilitates technology integration and provides students with opportunities to construct and generate experiments with scientifically testable questions.</td>
<td>Learning Cycle &lt;br&gt;Technology &lt;br&gt;Student Investigation</td>
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**Acknowledgment**

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**Reference**


**Internet Resources**

Council of State Science Supervisors. Rubric for evaluating essential features of classroom inquiry of instructional materials


Earth, Sun, and Moon SciPack

http://bit.ly/t8HxRT

NSTA Learning Center

http://learningcenter.nsta.org

NSTA Online Short Courses

http://learningcenter.nsta.org/products/online_courses/shortcourses.aspx

**NSSTA Connection**

View suggested websites and related information at www.nsta.org/SC1201.
<table>
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<tr>
<th>Article Title, Date, and Grade Level</th>
<th>Article Abstract</th>
<th>Type of Activity</th>
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<tbody>
<tr>
<td><strong>Science Object: Motion of the Moon</strong></td>
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<tr>
<td><em>Bringing Moon Phases Down to Earth</em> September 2008 Grades K–4</td>
<td>Teaching astronomy concepts does not have to be complicated or expensive. This article shares simple, hands-on activities to introduce students to lunar phases.</td>
<td>Observations Patterns</td>
</tr>
<tr>
<td><em>Teaching Through Trade Books: Moon Phases and Models</em> September 2008 Grades K–6</td>
<td>From the time they are very young, children are naturally curious about the Moon. They may wonder about the different shapes of the Moon when they look up at the night sky. In this lesson, primary students discover through direct observations and readings that the Moon’s shape follows a pattern. In the upper elementary lesson, students explore the reason for this pattern using a model.</td>
<td>Trade Books Observations Patterns Modeling</td>
</tr>
<tr>
<td><em>The Moon’s Phases and the Self Shadow</em> September 2008 Grades 5–6</td>
<td>In this article, the authors present a new way of teaching the phases of the Moon. Through the introduction of a <em>self shadow</em>, the authors illuminate students’ understanding of the phases of the Moon and help them understand the distinction between the shadows that cause eclipses and the shadows that relate to the phases of the Moon. The authors conclude with two simple demonstrations that help students further develop their understanding of the reasons behind the patterns of lightness and darkness in the Moon’s phases.</td>
<td>Modeling Student Investigation Demonstrations</td>
</tr>
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| **Science Object: Earth’s Seasons** | | |
| *Science 101: What Causes the Seasons?* January 2007 Teacher content | This article provides teachers with background information about the relationship between the Earth and the Sun at certain times of the year. Certain myths are broken, and teachers get a real lesson on what causes the seasons. | Teacher Content |
| *Science Shorts: The Reasons for the Seasons* April/May 2010 Grades 4–6 | Ask a fifth-grader why he or she believes the Earth has seasons, and the answer usually involves a mistaken notion about the Earth’s distance from the Sun. In this lesson, students employ a simple model to learn how Earth’s tilt and revolution around the Sun causes the seasons. | Observing Modeling Inferring Communicating |
| *Teaching Through Trade Books: A Season to Inquire* November/December 2004 Grades K–6 | Aside from learning about naturally occurring cycles that happen over time, trade books about seasons can help students learn about the cause of the seasons. These activity books deepen students’ conceptual understanding of seasonal change. | Trade Books Observations Predicting Student Investigation |

**Connecting to the Standards**

This article relates to the following *National Science Education Standards* (NRC 1996):

**Content Standards**

**Standard A: Science as Inquiry**
- Abilities necessary to do scientific inquiry (K–8)

**Standard D: Earth and Space Science**
- Properties of Earth Materials (K–4)
- Objects in the Sky (K–4)
- Changes in Earth and Sky (K–4)
- The Structure of the Earth system (5–8)
- Earth in the Solar System (5–8)

You were a physics teacher? [Sound of jaw hitting floor.] That’s right. After a few years of teaching high school physics to juniors and seniors, I decided it was time for a new challenge. That was when I serendipitously saw the opening for an elementary “science resource teacher.” Before making the switch from high school to elementary school, I had a period of time that I fondly recall as my “freaking out stage.” The realization of what I was about to do was sinking in. Teaching elementary school was going to be messy, in every possible sense. I decided to call my supervisor at the central office for some last-minute advice. She told me, “Good teaching is good teaching, no matter the grade level.” That comforted me.

After my first week in the elementary school, I felt like calling my supervisor again. This time I wanted to ask her whether she had a temporary lapse of sanity when she told me that “good teaching is good teaching.” The first few weeks were a shock, and I was sure that what I was doing was not “good.” I had pictured dewy-faced cherubs excitedly planning and conducting their first real scientific experiments, but what I ended up doing was more like herding cats. I was angry with my supervisor for giving me a false sense of security. Good teaching is not good teaching, no matter the grade level! Or is it? As time went on (and I began to hone my classroom management skills), I realized that what worked for the big kids works for the little kids. In teaching science to children ages 5–18, I have found that one principle cuts across all grade levels: children learn through play.

In this article, I suggest a novel way to use play; play is used to facilitate the lesson, not as the sole method of content delivery. Play can be used with all children, grades K–12, and it should be intentional and facilitated by the expert guidance of the teacher.

Link, Build, Assess

When I refer to “play,” I am referring to an activity deliberately planned by the teacher to engage the students (Gallenstein 2005). I am not referring to the general merit of doing fun science activities. Play is an informal time when the students are given materials (that may or may not be familiar to them) and expected to interact with these materials in such a way to:

1. Link: connect new knowledge with background knowledge
2. Build: provide experiences to increase background knowledge
3. Assess: informally evaluate the students’ background knowledge

Although play can be used in all parts of a lesson, using play during the link and engage portions will help students form ideas and make predictions. The teacher can then go into a more in-depth experiment with the students using the learning they gained through their play (see sample lesson, p. 62). In addition, play can
be used during the reflect portion to cement ideas and apply the learning to novel situations.

The beauty of play is that the teacher can link to, assess, and build background knowledge all at the same time. Secondary benefits of play include increased confidence using the laboratory equipment and increased engagement in the lesson.

**Link**

All lessons should begin by linking to students’ prior learning. In an attempt to gauge what students remember from previous classes, teachers may ask students a blunt question such as, “Who can explain what inertia is?” without providing any context for the concept. Undoubtedly, the teacher will determine that no one can remember. On the contrary, if students are engaged and given a context for recovering previous learning, they then have a better chance at remembering. This allows teachers to avoid wasting time reteaching concepts that were covered in previous science classes. Taking the inertia example, students can be presented with a scenario instead of a question in which they need to refresh their memory while forming new connections, and the teacher has an opportunity to informally assess the students’ prior knowledge.

**Build**

Play is a time when students who have little background knowledge can get caught up to their peers. While some students are building background knowledge, others are forming new connections. Students with no inertia experience can perform the penny trick alongside students who have experience and accomplish a different end. The teacher provides differentiated instruction while saving time.

It is important to use pertinent materials to elicit observations, inferences, and predictions from your students before the students perform an activity or investigation. Once I stood in front of a fifth-grade class and held up two fossils: one of a seashell, the other of a leaf. I asked, “Which fossil type are you more likely to find and why?” The students had no idea. I wanted them to infer that a hard object that does not decay quickly, such as a shell, is more likely to create a fossil than a soft, ephemeral leaf. In an attempt to relate the process of fossil making to something familiar, I asked the students whether they have ever pressed objects into clay to see the imprint. To my surprise, they had not. I realized that I should have had the students play with clay, seashells, and leaves before conducting the lesson to build background knowledge and draw out predictions. Merilee Rosberg (2003) contends that experience with pertinent materials builds background knowledge by developing concepts: “These concepts will ultimately become part of a growing classification system that will help children understand the world, their lives, and the people around them” (p. 4).

**Assess**

The class period after my initial lesson on fossils, I followed up with a video clip on how fossils are made and then led a class discussion on the topic. Next, I surveyed the class to find out how well they thought they understood fossils. On a scale of zero to five, the students’ average self-reported understanding level was a 3.53. Following the survey, I distributed clay, shells, and leaves. The students immediately made the observation that leaves cannot make fossils in the same way that shells can. As I probed the students, they stated that the leaf is “delicate,” that it was “easier” to make an imprint with the shell, and that the “clay would need to harden around the leaf instead of making a mold” to make a fossil. Afterward, I once again surveyed the students on how well they thought they understood fossils. This time the students reported an average score of 4.73. A secondary benefit of using play is increased student engagement, which will be discussed below; however, I will mention that the students also reported an increased interest in using the clay versus using the video clips and discussion.

Play can be easily differentiated to accommodate students of varying
Confident and Engaged

Play can also be used to rehearse experiment procedures. Before doing an experiment, have students play with the materials used in the experiment. As students manipulate the materials and go through a few practice trials, if each child has been assigned a job the children can practice doing the job, using their tools. For example, the timer should practice using the buttons on the timer, the measurer should practice reading the desired scale, and if the experiment requires any motions that may be unfamiliar (such as using a motion detector or an eyedropper), then the children should practice making the motions. You can also practice using the materials without taking data. For example, before a fourth-grade experiment on how the height of a ramp affects the speed of a marble, I have the students place the marble at different points on the ramp (e.g., where it will have the most potential energy or the most kinetic energy). The students become familiar with the materials while forming a new link to prior learning.

Practice increases the students’ confidence with using the materials by developing manipulation skills (Judd et al. 2002). Allowing the students to practice ensures fairness in your classroom because practicing enables all students to participate fully. If all of the students are not given the chance to participate fully, then some students may end up doing the experiment while others just watch. More often than not, kindergarten through college, boys...
2. Introduce the lesson by discussing the Earth–Sun relationship. Ask the students whether they have ever heard anyone say that the Sun rises and sets. Ask them what they think about this. Ask, “Is the Sun really moving?”

3. Explain to the students that the Earth rotates. Have the students partner up and act out being the Earth and the Sun. One student is the Sun and this person stands still. The other student is the Earth. Have this person rotate and when he or she faces the Sun, they should call out “day” and when they face away from the Sun, they should call out “night.”

4. Now ask the students to explain shadows. Ask, “Can you see your shadow in the dark?” They will recall from their experiences this morning that a light source (e.g., Sun) is necessary to produce a shadow.

5. Give each student pair a flashlight, a piece of paper, crayons, and several small objects such as blocks and figurines. The students should play with the flashlights and objects. Have one partner place an object on the paper while the other partner holds the flashlight. The first partner traces the shadow of the object and then the partners switch jobs. The students should be encouraged to shine the light at different angles and also to move the light around to different positions and observe the shadows. Instruct students never to shine the flashlight into anyone else’s eyes.

6. Discuss the students’ observations. Ask them what happened to the shadows when the flashlight was moved. Were they able to create different-shape shadows with the same object?

7. In the afternoon, go outside and return to the spot where the students traced their shadows. Now they should repeat their procedure and observe what is different about their shadows.

8. Back in the classroom, discuss the students’ observations. They will notice that the positions and sizes of their shadows have changed. Relate these observations to their observations with the flashlights. Ask the students to explain what happened. They may deduce that the Sun has moved in the sky.

9. Ask the students to recall that it is the Earth’s turning that causes day and night. Discuss how it looks like the Sun is moving, though it is really the Earth that is moving. Have the students pair up for “think-pair-share.” Ask, “Does the Earth or the Sun move?” “How does the Earth move?” “What causes day and night?” “What is happening when it is daytime on your side of the Earth?” (i.e., Are we facing toward or away from the Sun?)

10. Have the students act out the Earth and Sun again, this time with no teacher guidance. Observe if they act out their parts correctly (Sun is still, Earth rotates).

11. Give the students a few objects and ask them to predict what the shape of the shadow will be if the light source is in various positions.

Discuss these questions with your class.

1. Where will the person’s shadow be?

2. Which object can make this shadow?

3. When Mary goes outside, she notices that the shadow of a tree in her yard always seems to be in a different place. Can you explain to Mary why the tree’s shadow moves?
will jump at the chance to manipulate the materials and girls will be stuck being the recorder. However, the social interaction of play can enable children to “become more self-directed and gradually assume more responsibility” (Gallenstein 2005, p. 36). By having all of the students practice with the materials, all of the students will feel confident enough to collect data. Also, creating familiarity with handling the materials allows for an easy transition into a complex experiment—if the students feel comfortable using the materials, then they can concentrate on the actual experiment.

Play can also help students make connections to the real world. Students need to know why they are learning what they are learning. They need to see the value of their learning or they will not attach importance to it or commit it to long-term memory (Gallenstein 2005). Some concepts have direct and obvious connections to students’ lives. Let’s take the inertia example once again. Once students understand inertia, they understand why it is important to wear a seatbelt. But other topics are less tangible. Here is my favorite example: phases of the Moon. Was there ever a topic less understood by children or adults? Using play can make this seemingly intangible concept tangible! I remember the first time I understood the phases of the Moon. It was not after I memorized all of those diagrams for my college astronomy class. It was when I was preparing to teach the phases of the Moon to my sixth graders. I had to physically act it out, and I realized that the students would understand if they acted it out, as well. I used a ball to represent the Moon and a lamp without a shade to represent the Sun. The students held up the ball, rotated in place, and observed the light/dark contrasts. Playing with the model enabled me to create mental images of the Earth, Moon, and Sun in various positions. My kinesthetic experience enabled me to finally understand those abstract diagrams.

Although play time is less structured than experiment time, it is important to guide play with leading questions (Gallenstein 2005). Before having the students play, ask yourself what knowledge or experiences you want the students to gain from their play. Craft these essential learnings into questions to ensure that the students know their purpose.

**Conclusion**

Transitioning from helping high-schoolers find sin⁻¹ on their TI-83s to helping kindergarteners tie their shoes was exactly what I was looking for: a challenge. Reflecting on my experiences with the big kids and the little kids, I have gleaned a best practice that transcends age or developmental level: *kids learn through play*. Play techniques can be simple and incorporated into any preexisting curriculum. In summary, hands-on, engaging, inquiry-based science grounded in the context of the real world looks much the same at any level. Good teaching is good teaching, after all.

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**References**


**Connecting to the Standards**

This article relates to the following National Science Education Standards (NRC 1996):

**Content Standards**

**Grades K–8**

**Standard A: Science as Inquiry**

- Abilities necessary to do scientific inquiry

**Grades K–4**

**Standard B: Physical Science**

- Properties of objects and materials
- Light, heat, electricity, and magnetism

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Q: What causes the tides?

A: Anyone who’s been near the oceans or even really large bodies of water such as the Great Lakes knows that there are tides, in which the water moves toward and away from the shore at different times of the day. Most people also know that the Moon has something to do with this process. Beyond that, the tides are rather misunderstood by lots of people. That’s no surprise because the process doesn’t exactly have your average, commonsense explanation.

The Activity: Rubber Bands

As usual in this column, to understand something I’m going to ask you to do an activity or two. Find three rubber bands that are the same length and thickness. If dexterity is your strong suit, then that’s all you need at the moment. If you’re not so nimble with your fingers, you’ll need a friend to help you. If you have no friends, get a board of any kind and drive a couple of nails into the board far enough apart that you can stretch the rubber bands between them. No matter which of the three methods you choose, you need to end up with the three rubber bands stretched between two points as shown in Figures 1a and b.

Here’s where it gets difficult if you’re doing this without nails in a board or a friend. Pull each of the rubber bands to the side with a different force, meaning you pull one with a small force, one with a medium force, and one with a large force. The result should be something like Figures 2a and b.

Okay, what great lesson does this teach us? It teaches us that pulling on different objects with different forces separates them if they’re originally together, and separates them even more if they’re already separated. Earth-shattering, I know, but crucial to understanding the tides.

Force of Gravity

We have to switch gears now and discuss the force of gravity. We most often think of gravity as the force that Earth exerts on objects, but there is in fact a gravitational force between all objects that have mass. Your coffee cup exerts a gravitational force on you and you exert a gravitational force on your coffee cup. Your couch exerts a gravitational force on everything around it and vice versa. The Moon exerts a gravitational force on everything around it, including Earth and everything on Earth. The Sun exerts a gravitational force on everything around it, which is why all of us planets including the Pluto formerly known as planet (yeah, I meant to write it that way—think about it), orbit around the Sun.

One important characteristic of the force of gravity is that it gets weaker with distance. The gravitational force a chair exerts on you is weaker the farther you are from the
chair (and stronger the closer you are to the chair). The gravitational force between all celestial objects (e.g., stars, planets, moons) gets weaker the farther apart the objects. This “weaker with distance” thing is a good deal, too. If gravitational forces did not get weaker with distance, then the gravitational force between all the objects in the universe would be so strong that the universe would collapse in a relatively short time.

Now that we know a few things about gravity, let’s head back and look at the interactions between the Moon and Earth. Just to reinforce the idea about the strength of gravitational forces, Figure 3, p. 68, shows the Moon and the relative sizes of the gravitational forces it exerts on chairs (by using different-size arrows) that are different distances from the Moon. Note that this force is always a pull (not a push), and as we said, becomes weaker the farther away you are. There’s nothing special about using chairs in the drawing except that the mass of the object being pulled by the Moon affects the size of the gravitational force. We have to use the same object for comparisons, and well, why not use a chair? Certainly you’ve seen chairs that big!

Three Different “Things”
To take this a little further, we’re going to consider Earth to be made of three different “things” that are together and actually somewhat separated rather than being exactly together. Those three things are the main part of Earth itself, the water on the surface of Earth that’s closest to the Moon, and the water on the surface of Earth that’s farthest from the Moon. See Figure 4, p. 68, and note that this drawing is not to scale.

The Moon exerts a gravitational force on each of these three separate things (Earth, water on one side of Earth, plus water on the other side of Earth), and because each of the things is a different distance from the Moon, the Moon exerts gravitational forces of different strength on each one. The different strengths of these pulls are shown in Figure 5, p. 69, with the length of the arrow representing the strength of each pull. Again, the lengths of these arrows aren’t drawn to scale. The differences in gravitational pulls aren’t as large as the arrows indicate, but the differences do exist.

We’re pulling on these three different things with three different forces. Sure sounds like rubber bands to me. Do you think those three things will separate, just as the
rubber bands did? If you don’t think that, you should change your thinking, because that’s what happens. Take a look at Figure 6. If you’re still bothered by nothing but pulls (and no pushes) causing three things to separate, think of it as the water closest to the Moon being pulled away from the main part of Earth and then the main part of Earth being pulled away from the water farthest from the Moon.

Bulge of Water
What we end up with is a bulge of water (just think of it as the oceans) on one side of Earth and a bulge of water (oceans on the other side of Earth) on the other side of Earth. To see how this causes tides, you need to do one of two things. Photocopy Figure 6, download it from the Science and Children website (see NSTA Connection), or make a rough sketch of Figure 6 on a separate piece of paper. Then cut the “bulging ocean” parts of the drawing away from the Earth part, tape the ocean parts to a table or hard surface, and tape a toothpick to the Earth part of the drawing. You should have something like Figure 7, p. 70.

Hold onto the toothpick and rotate “Earth” as shown in Figure 7 (Note the proper direction of rotation—if you do it backward you have the Sun rising in the West!). Notice that the toothpick is at the North Pole of Earth, so as you rotate, different parts of Earth at the equator encounter the ocean bulges that are taped to the table. Now imagine you’re at one of those spots on the equator. As Earth

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**Figure 3.**
The gravitational force the Moon exerts on the chairs is smaller the farther away a chair is from the Moon.

**Figure 4.**
rotates, the place where you are on the equator encounters water that slowly rises and then falls as you go by the bulge. These are the tides, and the bulges go by you twice a day. Take another look at Figure 7, and notice that the water bulges are staying put while the water is traveling with the spinning Earth. The bulges are always directly in line with Earth and the Moon (or also the Sun, see below), whereas the different parts of the oceans move through the bulge areas as Earth rotates.

To summarize, that gravitational pull gets weaker with distance means the pull of the Moon creates bulges of water on either side of Earth. As Earth (including the water) rotates “underneath” the bulges, different parts of Earth experience high and low tides. What makes this whole concept a bit difficult to grasp is that the separation of the water and Earth results from a pull in a single direction (toward the Moon), even though it seems that there ought to be a pull on one bunch of water and a push on the other. If that confuses you from time to time, think back to those rubber bands.

Not the Entire Story
I’ve only told you half the story. It’s not just the Moon that causes tides on Earth. The Sun participates, too. The Sun exerts its own gravitational pull on Earth and on the water on opposite sides of Earth, just as the Moon does (Figure 8, p. 70).

Now, you might know that the Sun, the Moon, and Earth move relative to each other, so they find themselves in different locations. Figure 9 shows a number of these different locations and the effect each position has on Earth’s tides. Note that the sizes of Earth, the Sun, and the Moon are not to scale, and that the water bulges on Earth are greatly exaggerated. Sometimes the tidal effects of the Moon and the Sun reinforce each other and sometimes
they work against each other. When the Sun and Moon's tidal effects reinforce each other, we have what are known as spring tides (has nothing to do with the season spring), and when the effects tend to cancel each other, we have what are known as neap tides.

Notice that the spring tides occur during new Moons and full Moons. That has nothing to do with the brightness, or lack thereof, of the Moon, but rather the locations of the Sun and Moon. If the Sun and Moon are lined up (as with new and full moons), you get high tides. The situation with the full Moon is also interesting because it points out that the Sun and Moon don't have to be on the same side of Earth to get high tides. That's because the formation of tides has everything to do with things (i.e., Sun and Moon) pulling and nothing to do with things pushing. Again, back to the rubber bands if you're still a bit confused.

Not All That Simple
There are undoubtedly people reading this column who are thinking the author has no idea what he's talking about. There are places on Earth where they don't get simply two high tides and two low tides per 24 hours, and there are places such as the Bay of Fundy where the high and low tides are enormous compared to other places on Earth. These are because rivers, deltas, bays, and various other geologic shapes affect the movement of the ocean's waters, resulting in incredibly high or low tides or situations where water gets...
Figure 9a. Effect of Moon and Sun reinforce each other, creating very high and very low tides. These are called spring tides, and they also happen at a “new” Moon.

Figure 9b. This is also a spring tide. Even though the Sun and Moon are on opposite sides of Earth, their effects on the tides reinforce each other. Think back to the rubber bands and remember it all has to do with pulling. No pushing is involved. Note that this spring tide’s configuration happens during a full Moon.

Figure 9c. Neap tides. The tidal effect of the Sun and Moon cancel each other, so the high tides aren’t as high as they would be in the spring tide situation, and the low tides aren’t as low as they would be in the spring tide situation.

“held up” for a while and then released, causing more than two high and low tides per day. And speaking of not knowing what one is talking about, it’s ironic that I’m writing a column on tides 30+ years after an embarrassing moment. I was in graduate school in physics, and a friend asked me what caused the tides. I hemmed and hawed and drew pictures and thought to myself, “I used to know this.” That was one of my first awakenings to the fact that I had spent a great deal of time as an undergraduate memorizing physics concepts rather than understanding them. This was one of the most valuable lessons I ever learned, and the friend was kind in helping me get over the blow to my ego!

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.
Earth-Friendly Living

This book is part of a series that targets the interest level of students in grades 3 through 6 with a reading level of about grades 3 and 4. Although each book has some technical vocabulary, the actual photographs that are used throughout the books further explain the content.

Earth-Friendly Living presents current information on why it is so important to reduce, reuse, and recycle. Topics include what an Earth-friendly kitchen might include, using products that are environmentally safe, and what can be done now to protect the environment.

Vocabulary is bolded in the text and defined in a one-page glossary. Facts supporting the content are stated throughout and highlighted in color. Suggestions are stated as to what can be done now for an Earth-friendly environment today and tomorrow. The books in this series could be used by teachers as a springboard for future research either individually or as the basis for group reports.

Ruth Ruud

Gravity All Around (p. 72)
By David J. Conrad
Great for discussing motion and forces of motion. (Grades K–1)

Geology of the Pacific Northwest (p. 73)
By Cynthia Light Brown
15 different activities that range from making a glacier to drawing coastlines. (Grades 4–7)

Mission to Mars (p. 74)
By Eve Hartman and Wendy Meshbesher
Presents the challenges implicit in this mission. (Grade 3–6)

Gravity All Around

Why do things fall down and not rise up? This question and other gravity-related topics are discussed in this outstanding book. The striking photographs on each page enhance the narrative of gravity, as does the discussion of famous scientists and their work.

After viewing the close-up photography, children will see easily what the text is explaining. The book concisely goes through topics, such as what gravity is; what scientists Aristotle, Galileo, and Newton taught about gravity; and what has more or less gravity. An activity is included to test the strength of gravity compared to the strength of magnets.
The book includes a glossary of science-specific vocabulary, a list of other recently published books about gravity for more reading, a list of websites to visit, and an index. I can’t wait to use Gravity All Around with my younger students in a whole-group setting. It’s appropriate for kindergarten through grade 1, has a reading level of 1, and is an Accelerated Reader book. Teachers will be able to use this outstanding book for years to come when discussing motion and forces of motion.

Kimberly Elpers

Geology of the Pacific Northwest
By Cynthia Light Brown.
128 pp. $15.95.
Nomad Press. (Grades 4–7)

This excellent little book about the geology of the Pacific Northwest makes learning Earth science both fun and practical. The information is accurate, and there are definitions and examples of the layers of the Earth, plate movement, plate tectonics theory, and the manner in which these factors influence the different types of boundary movement in this region. This book describes the land features of volcanoes and how glaciers carve the land into different basins and plateaus. The vocabulary is clear and relevant.

This book contains 15 different activities that range from making a glacier to drawing coastlines using fractals. Earthquakes, climate, and river systems are described. The effects of

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1. Mix a level tablespoon of Epsom salt (magnesium sulfate) with 2 tablespoons water on a plate.

2. Fold a paper towel into quarters and roll it into a ‘log’. Lay it in your mineral water ‘swamp’ to evaporate until dry.

3. Wood petrifies (turns to stone) as dissolved minerals in water slowly replace wood fiber. How might your log model this process? How might it be different?

4. Wait several days until your log is completely dry.
   a. Evaluate your prediction.
   b. Does your petrified log burn?

OBJECTIVE
To model how dissolved minerals petrify wood.

LAB NOTES
Photocopy the activity above for each student or lab group.

Step 1. More than a level tablespoon will create problems. A mineral crust will form and slow the drying of the “log” from a matter of days to possibly weeks.

EXTENSION
Grow stalactites and stalagmites! Use a strip of paper towel to wick, then drip, a solution of Epsom salt through a gap of about 1 cm from a smaller plate resting on a larger one. The solution will first flood and crystallize on the bottom plate, but as the drip slows, first a stalactite forms on the end of the towel, then a stalagmite where the drips lands. Slower drips and drier air favor faster growth. Add more solution to the top plate as needed. These structures are hollow and will crumble easily.

MATERIALS
• Epsom salt (magnesium sulfate).
• Plate(s) and tablespoon.
• Paper towel, candle, and matches.

ANSWERS
3. Similar: Dissolved salt will likely soak into the paper towel and remain there as water evaporates. The log might harden like stone. Different: These minerals will add to, but probably not replace, the paper fibers over the relatively short time needed for this lab. (Actual petrification occurs over hundreds of years.)

4a. As predicted, magnesium sulfate was absorbed by the towel and hardened as the water evaporated away.

4b. Like petrified wood, this log will not burn. When exposed to flame, magnesium sulfate melts and bubbles, turns brittle and starts to crumble. The paper blackens a bit but does not burn.

EVALUATION
Q. How does wood petrify?
A. Over a very long time, water slowly replaces wood fibers with dissolved minerals.

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changes on the land and humans are developed nicely and masterfully connected to the basic concepts.

Having been to the Pacific Northwest, I know that there are temperate rain forests and epiphytes here in the United States. With drawings, descriptions, large print, and interesting facts, the book enables this unique region to come alive for students who have not been able to experience it. The book will hold students’ interest, adding new vocabulary on each page. This would be an excellent resource for any teacher who teaches Earth science. Although it’s particularly relevant to those who live in the Pacific Northwest, the concepts are broad enough to apply to any course at this level.

Teri Cosentino

Mission to Mars

The six-volume Science Missions series presents timely, focused discussions of science issues students will find in the news. Each 56-page book provides sufficient background material on a topic for a student reader to make sense of a controversy. In essence, the authors have dug beneath the hype that accompanies the presentation of science in the media to give students the tools with which to make informed judgments based on empirical data and observation. Each volume teams an experienced children’s book author and

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In *Mission to Mars*, the young reader will find a lucid and thorough treatment of the prospects of astronauts someday traveling to and colonizing Mars. From exposure to solar wind, through the physiological problems posed by living for months in a low gravity environment, to the extensive resources that will be needed on such a trip, we learn about the challenges that would be implicit in a manned mission to Mars.

Lacking in the book is a discussion of whether such a mission is advisable at all. Hartman evidently proceeds from the assumption that human colonization is both desirable and inevitable. Given that point of view, students will find the analogy to the Biosphere 2 project from the 1990s, with its many accomplishments and challenges, a realistic template to consider for Mars colonization.

*Cary Seidman*

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